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Time travel and coincidence-free local dynamical theories

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Abstract I criticize Lockwood's solution to the "paradoxes" of time travel, thus endorsing Lewis's more conservative position. Lockwood argues that only in the context of a 5D space-time-actuality manifold is the possibility of time travel compatible with the Autonomy Principle (according to which global constraints cannot override what is physically possible locally). I argue that shifting from 4D space-time to 5D space-time-actuality does not change the situation with respect to the Autonomy Principle, since the shift does not allow us to have a coincidence-free local dynamical theory.

1 The Paradoxical Train: Local and Global Constraints

In his book *The Labyrinth of Time*, Michael Lockwood has argued that the possibility of time travel poses a threat to the Autonomy Principle:

(AUTONOMY) Any configuration of matter and energy that is *locally* consistent with the laws of physics is also *globally* consistent with these laws[1]

If AUTONOMY holds, configurations of matter and energy that are allowed by the laws of physics, given their immediate surroundings, cannot turn out to be impossible given the way in which matter and energy are globally distributed. For instance, if we buy a functioning

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[1] [16, Lockwood, 2005: 172 and 327]. See also [4, Deutsch and Lockwood, 1994: 71]

electric stove, and we connect it to the power supply, the stove will start to produce heat, regardless of what is happening in other areas of the universe. Of course, something in the surroundings of the stove may hinder its normal functioning: a high level of air humidity might damage some essential part of its circuits, say. But what happens far away from its surroundings — on the Moon or on Mars — cannot constrain the way the stove works. The idea underlying the AUTONOMY is that global constraints are just the result of "adding up" local ones, and thus cannot override local possibilities.

As Lockwood points out, AUTONOMY is not only very intuitive, but it underlies common experimental practices in science: "[w]e normally regard it as a live option to set up our apparatus in any state allowed by physical law, and assume that we can rely upon the rest of the universe to take care of itself." [16, Lockwood 2005: 172]. However, in time travel scenarios AUTONOMY is no longer secured.[2] A time travel scenario is one in which the space-time manifold is curved in such a way as to encompass closed time-like curves (CTC). A moving object or a light signal that follows a CTC can start at a spacetime point with temporal coordinate *t'* and reach a point with temporal coordinate *t* that temporally precedes *t'*, without ever going faster than light. In such scenarios, backwards causation is allowed: an event *c* can be the cause of another event *e*, even if *e* is earlier than *c*.[3] In other words, time travel scenario are ones in which the thesis of the physical possibility of time travel (TIME-TRAVEL below) holds.

(TIME-TRAVEL) Time travel is physically possible, *viz.* the laws of physics allow CTC

In order to see why AUTONOMY and TIME-TRAVEL are in tension, consider the following example[4]: an automated train is programmed to enter a tunnel at time *t'* if and

[2] [2, Arntzenius and Maudlin 2002] argue that this is false. I think their arguments are convincing, but in this paper I will grant Lockwood and Deutsch their point and pursue another line of criticism. In general, there are several plausible objections to AUTONOMY: for instance, it seems to be false even outside time travel scenarios, given that many theories encompass not only dynamical evolution equations, but also constraint equations on initial data. However, for the purpose of the present paper, I will set aside those worth discussing issues. Thanks to an anonymous referee who helped me clarify this point.

[3] Throughout the paper I am setting aside relativistic considerations and I am always speaking as if a reference system of temporal and spatial coordinates has been fixed. This simplification is just for ease of exposition. Also, I am considering only *backwards* time travel. Although forward time travel scenarios raise interesting questions too, I am not touching upon them here.

[4] [16, Lockwood 2005: 169-72].

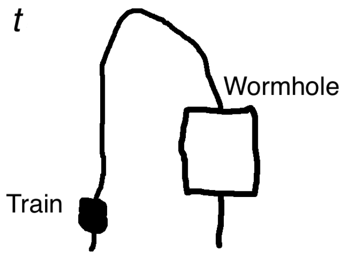

Fig. 1

Fig. 2

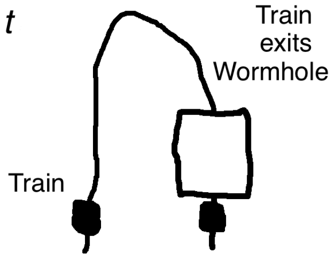

Fig. 3

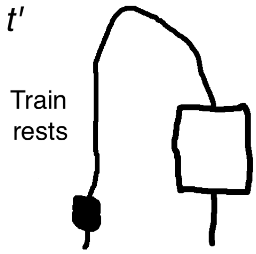

Fig. 4

only if at *t* (ten minutes before *t'*), it does not detect a train coming out of the tunnel. It is surely possible to build such a device. However, if the tunnel is a wormhole such that if an entity *x* enters it at *t'*, *x* comes out of it at *t* (ten minutes before *t'*), it is paradoxical to think that the device will work properly. Suppose, as in Fig.1, that at *t* no train comes out of the wormhole. Then the train will enter the tunnel ten minutes later, at *t'* as in Fig.2. But if it enters at *t'*, then at *t* it would have exited the tunnel, contrary to what we assumed.

Analogously, if at *t* the train exits the tunnel (see Fig.3), then after ten minutes, at *t'*, it will not enter the tunnel (see Fig.4), and hence it would have not exited from the tunnel at *t*, contrary to what we have assumed. Therefore, neither of the behaviours allowed by the device governing the train (when properly functioning) leads to a consistent sequence of events. Hence the apparent paradox.

In this scenario, the absence (or the presence) of a train coming out of the tunnel at *t* represent a *boundary condition* that constrains what can happen to the train and the device governing it. That is, after *t* certain options that appear to be open if we consider only the surroundings of the train are ruled out by the global distribution of matter and energy, contrary to what AUTONOMY says. Such a global constraint does not determine *what* will happen to the train, but it determines that *something* preventing the train from entering the tunnel will happen (if no train came out of it at *t*, and *mutatis mutandis* if a train comes out of it at *t*). In other terms, the global situation requires that some event or other stands in the way between the train and its entering the tunnel: maybe a meteorite will hit it right after *t*, or the device will jam, or...

Now, there is disagreement over the status of such events – sometime called "coincidences" – and the acceptability of appealing to them as a way to avoid paradoxical outcomes in time travel scenarios.[5] For instance, [10, Horwich 1975] argues that the fact that time travel entails that coincidences happen makes time travel *not* impossible, but improbable[6], and [2, Arntzenius and Maudlin 2002] argue that coincidences require conspiracies, that is unacceptable constraints on initial data.[7] A thorough discussion of the issue would be beyond the scope of this paper. What I want to stress here is that TIME-TRAVEL seems to require (at least given our present knowledge of physics) that only on the ground of *global* constraints can we *explain* why something will prevent paradoxical outcomes from happening. Such an explanation is not 'coincidence-free' in the sense that it is based only on global constraints and not on a local dynamical theory. Indeed, from a local standpoint, a paradoxical outcome doesn't look paradoxical at all: it is something that, for all we know, might have happened, had the circumstances been (slightly) different. Of course, circumstances *could not* have been that way, and that is why the paradoxical outcome *is* paradoxical.

My point here is not to defend (or attack, for that matter) the idea that "coincidences" of this kind are in some sense or other acceptable. Rather, I wish to point out that in the presence of CTC, certain configuration of matter and energy that are consistent with their surroundings are ruled out by the requirement that those configurations should be also globally consistent. Therefore, in the presence of CTC, global constraints seem to override what is locally possible according to the laws of physics, and if that is the case, than TIME-TRAVEL is incompatible with AUTONOMY. Thus, any attempt to reconcile TIME-TRAVEL and AUTONOMY requires a coincidence-free, local dynamical theory of the transmission of

[5] [15, Harrison 1971], [24, Thom 1975], [13, Lewis 1976], and [20, Riggs 1997] suggest solutions that entail that such events will happen in travel scenarios, and they all stress that they are compatible with ordinary physics.

[6] The argument is criticised by [22, Sider 2002]. A version of it is defended by [26, Vihvelin 1996].

[7] In criticising their position, [6, Dowe 2007] rightly points out that what prevents the paradoxical outcome to happen does not need to be "already there" (as in the case of a meteorite that is following its trajectory), since it may arrive from the future as well (as if out of the tunnel arrived something that blocks or destroys the train). See also [5, Dowe 2003].

matter and energy throughout wormholes (or whatever else does the trick of taking back in time matter and energy).[8]

2 How Many Dimensions Does Time Have?

The case of the "paradoxical" train just discussed might remind the informed reader of the grandfather "paradox" and the solution to it proposed by David Lewis in his seminal [13, Lewis 1976]. Jim travels back in time with the intention to kill Grandpa — his grandfather — before Grandpa conceives Jim's father. Killing Grandpa seems an easy thing to do for someone who has a loaded gun, is a good shot, and finds himself close enough to the target. This is precisely the situation Jim finds himself in after arriving in the past. Yet, if Jim kills Grandpa, Jim will not be born, and thus he cannot enter the time machine and carry out his fatal plan. But if Jim does not kill Grandpa, he will take the time machine and find himself in a position to kill Grandpa. How is this possible? Lewis considers the possibility that time has a further dimension:

> "It is tempting to reply that there must be two independent time dimensions; that for time travel to be possible, time must be not a line but a plane. [. . .] Then a pair of events may have two unequal separations if they are separated more in one of the time dimensions than in the other. The lives of common people occupy straight diagonal lines across the plane of time, sloping at a rate of exactly one hour of time$_1$ per hour of time$_2$. The life of the time traveler occupies a bent path, of varying slope."([13, Lewis 1976:145])

Consider, in Fig. 5, the various T^I_n and T^{II}_n as the two temporal coordinates of what Lewis calls time$_1$ and time$_2$. A non-time traveler's life would follow the straight diagonal line A, whereas the life of a backwards time traveler could look like A till it reaches the point with coordinates T^I_2 and T^{II}_2 and then, following segment B, bent back to the point with coordinates T^I_3 and T^{II}_1.[9]

[8] A 'coincidence-free' local dynamical theory is one on which an explanation that is coincidence-free in the sense introduced above can be based. Thanks to anonymous referees for useful comments on the relation between the issue of "coincidences" and that of the compatibility between TIME-TRAVEL and AUTONOMY (again, only the latter is my main focus), and for having suggested the more general point on the requirement of having a coincidence-free local dynamical theory.

[9] The two dimensional model that Lewis briefly discusses is the one in [17, Meiland 1973], which is fundamentally B-theoretic (i.e. tenseless) in spirit. More recently, A-theoretic (i.e. tensed) two-dimensional

In a two-dimensional model, it is easy to see how Jim's puzzle can be solved. If Jim's life follows the bent path in the picture above, once he reaches T_2^I and T_2^{II} he will travel back in time along the vertical axis, but *not* along the horizontal axis. Therefore, the past that he reaches in T_3^I and T_1^{II} can be different from the past in T_1^I and T_1^{II}. In the latter, Grandpa lives and begets Jim's father, since Jim was born some time afterwards at a point along line A; in the former it may well be the case that Grandpa is killed by some mysterious stranger from the future. Although the two-dimensional model provides a resolution to the paradox, this is not the solution of the puzzle that Lewis favors:

> "On closer inspection, however, this account seems not to give us time travel as we know it from the stories. When the traveler revisits the days of his childhood, will his playmates be there to meet him? No; he has not reached the part of the plane of time where they are. He is no longer separated from them along one of the two dimensions of time, but he is still separated from them along the other. I do not say that two-dimensional time is impossible, or that there is no way to square it with the usual conception of what time travel would be like. Nevertheless I shall say no more about two-dimensional time. Let us set it aside, and see how time travel is possible even in one-dimensional time." ([13, Lewis 1976: 145])

As the passage above makes clear, Lewis explicitly endorses what we may call the principle of Unity of Time (UNITY below), which is incompatible with a two-dimensional conception of time.

(UNITY) The time line (namely the temporal dimension in which we and everything else are located) is unique[10]

The fact that Lewis is unwilling to jettison UNITY in order to save the possibility of time travel explains why his solution to the grandfather "paradox" parallels the case of

models of time have been discussed in the context of time travel by [25, vanInwagen 2009], [12, Hudson and Wasserman 2009], and [3, Berstein 2014].

[10] UNITY is vague, given that what the "temporal dimension" is may depend on the background theory that we assume. However, I take the basic idea to be clear enough: whatever counts as the (closest approximation of the) temporal dimension in the background theory is unique. For instance, UNITY is meant to be compatible with special and general relativity: even if relativistic space-times have no frame-independent temporal dimension, it is neither the case that the temporal coordinate duplicates within each frame of reference, nor that the "negative" coordinate of the four-dimensional manifold is not unique.

the paradoxical train that we discussed in the previous section. The *global* consistency of the situation requires that certain options that look *locally* consistent be ruled out: since Jim *is* Grandpa's grandson, if he tries to kill Grandpa before Grandpa begets Jim's father, Jim is bound to fail. Again, some "coincidence" will prevent Jim from killing Grandpa: he will slip on a banana peel, the gun will jam, he will mistake Grandpa's best friend for Grandpa. . . Indeed, the paradoxical train case can be seen as a version of the puzzle that is "purified" of any reference to human capacities and issues of free-will.[11] And in both cases, it is the endorsement of UNITY that forces us to abandon the AP, in favor of a "coincidence" solution to the puzzle. Therefore, the tension is not (necessarily) between AUTONOMY and the possibility of time travel, but we are rather confronted with a seemingly inconsistent triad: TIME-TRAVEL, AUTONOMY, and UNITY. The question, then, is: which one (or ones) shall we give up?

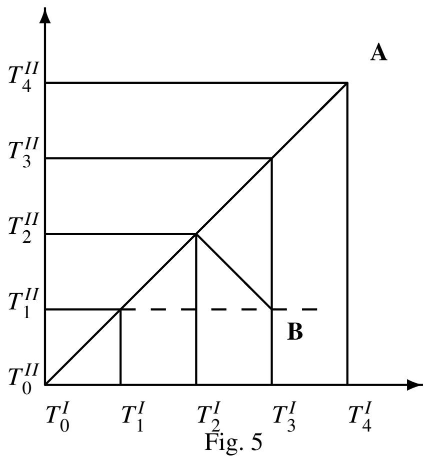

Fig. 5

3 Making the Case for a 5D Manifold

Lewis, as we have seen, keeps TIME-TRAVEL and UNITY. Others, like [11, Horwich 1987: 119-24], keep AUTONOMY, but argue that any "attempt" to change the past must be *de facto* unlikely to happen, given that they would require repeated coincidences. Lockwood argues that the best way to accommodate the triad is to get rid of UNITY. Given that contemporary physics suggests that backward time travel, at least at a quantum scale, is likely to happen, and that AUTONOMY is methodologically sound, jettisoning UNITY seems to

[11] An analogously "purified" version of the grandfather paradox is in [7, Earman 1972], who arrives at conclusions that are different from Lewis's, although similar in spirit. See also [21, Sider 1997].

be the best option, unless there are strong reasons against it. Now, two-dimensional time does not have support from physical theories (see [18, Richmond 2000]). However, adding an extra dimension to *time* is not the only way to dismiss UNITY. Lockwood's favorite interpretation of quantum physics, the many-mind interpretation, has it that the "arena of reality" – the manifold where all physical events take place – is not confined to one temporal dimension and three spatial ones, but it is a *five-dimensional manifold* composed by three spatial dimensions, one temporal dimension, and one dimension of actuality. In this 5D space-time-actuality manifold, the dimension of actuality is orthogonal to the other four, and entities can be multi-located along it. Thus, the dimension of actuality embeds a 4D manifold, and it "expands" the possibility of being located at any of the coordinates along its dimensions. In particular, an entity that is located at coordinate *t* of the temporal dimension can be multi-located at many distinct coordinates *w*, *w'*, *w"*, . . . along the dimension of actuality, and that means that the time line is *not unique* in the sense required by UNITY.[12]

Even more importantly, if we drop UNITY by endorsing the 5D space-time-actuality manifold rather than adding a dimension to time, we can have backward time travel without renouncing AUTONOMY, within a physically plausible scenario. Consider again the paradoxical train. At *t*, at point of actuality *w* (see Fig.6), the train does not detect a train coming out of the wormhole. Hence, at point of actuality *w* (see Fig.7), it enters the wormhole at *t'*. By entering the wormhole the train will be going back in time along the temporal dimension, but also "sideways" along the dimension of actuality, thereby ending up at a *different* point of actuality *w'* (see Fig.8), where it finds a younger version of itself. This version of the train detects a train coming out of the wormhole at *t*, and hence it won't enter the tunnel later on at *t'* (see Fig.9). In a 5D manifold, the train gains an extra "degree of freedom", and this frees it (and the device that governs it) from the global constraints that we have seen

[12] As an anonymous referee rightly noticed, Lockwood's proposal is roughly that of a branching time structure. However, I will stick to the original formulation in terms of the dimensionality of the manifold, rather than rephrase it in terms of its topological structure. Firstly, I wish to be as faithful as possible to Lockwood's text. Secondly, a five dimensional manifold is *per se* incompatible with UNITY, given that the temporal dimension is multiplied (or split) into multiple temporal dimension in the different points of actuality, but I am unsure about how to rephrase such incompatibility in terms of a branching time structure. Besides, I am conscious that there may be deeper problems concerning the the possibility of formulating a mathematical and physical model of such a spacetime structure, regardless of the basic language from which we start (as also the same anonymous referee notices). However, for the purpose of the present paper I grant to Lockwood the general viability of the proposal.

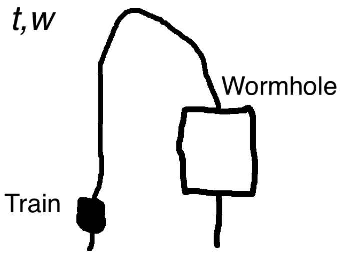

Fig. 6

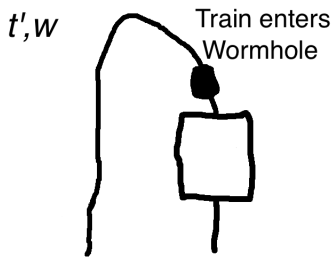

Fig. 7

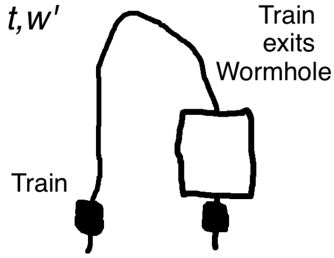

Fig. 8

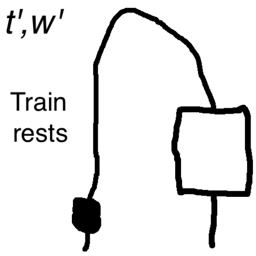

Fig. 9

at work in the 4D scenario. If the train detects no train coming out of the tunnel at *t*, as the point *w* of actuality, it is free to enter the wormhole without any "coincidence" standing in its way (see Fig.6 and 7). If the train detects a train coming out of the tunnel at *t*, as at point *w'* of actuality, it is free to remain without any "coincidence" forcing it somehow to enter the wormhole (see Fig.8 and 9). In other terms, within a 5D manifold background, it seems possible to formulate a coincidence-free, local dynamical theory of the transmission of matter and energy through past-directed wormholes. Lockwood concludes that, if we have to make room for actual time travel (as modern physics seems to require), the best "arena" for physical phenomena is a space-time-actuality manifold, in which time travel is possible and AUTONOMY is not violated. As I will argue in the sections below, the problem with Lockwood's proposal is that once we are clear about the relation between the dimensions of the 5D manifold and the individuals that move through its time-like paths, we also see that in a 5D manifold with closed time-like curves AUTONOMY is violated as well (or, more precisely, that it is violated *if* it is violated in a 4D manifold)[13].

[13] The idea of a 5D space-time-actuality manifold is close to that of a multiverse. Some maintains that in a multiverse backwards time travel would actually be "universe-hopping", namely a kind of *space* travel through universes. See [9, Hewlett 1994], [1, Abruzzese 2001], [19, Richmond 2003], and [8, Effingham 2012.] One might expect such worries to carry over to the 5D case. For my purposes, however, this does not

4 Whither Autonomy?

In what follows I will argue for my main point, namely that augmenting the dimension of the manifold won't give us AUTONOMY in the presence of TIME-TRAVEL, and thus, dialectically speaking, Lewis's "coincidences" solution to the puzzles of time travel is to be preferred over the 5D solution.[14] Remember what the Autonomy Principle states:

(AUTONOMY) Any configuration of matter and energy that is *locally* consistent with the laws of physics is also *globally* consistent with these laws

In a four-dimensional manifold, TIME-TRAVEL leads us to abandon the AUTONOMY because global coherence imposes constraints on what alternatives are locally possible. Consider Fig. 6 and the 4D case again. Given that the train at *t* has not come out of the tunnel, it cannot enter the tunnel at *t'*, and the situation as in Fig.7 is ruled out. In other terms, in a 4D manifold, global constraints impose that the train cannot enter the wormhole at *t'*, given that it does not exit the wormhole at *t*. The constraints are global because nothing locally explains this incompatibility. The local dynamical theory only tells us that the train will enter the wormhole at t' (and hence reach time *t*) if it does not detect a train out of the wormhole at *t*, and that it will not enter the wormhole at t' (hence not reaching time *t*) if if does detect a train out of the wormhole at *t*. In order to explain it, we have to look at how *t* and t' are connected through the wormhole. Now, how does the 5D case differ from the 4D case?

The 5D strategy for saving the AUTONOMY consists in providing the train with a further degree of freedom. While it is impossible for the train in a 5D manifold to enter the wormhole at *t'* at point of actuality *w* and exit at *t* in the same poit *w* (as it is in the 4D case), it is possible for it to exit at *t* at a different point of actuality *w'* (as in Fig 8). A further degree of freedom does indeed provide the train a "way out" to the stumbling into a coincidence that prevents it from entering the tunnel at *t'* in *w* – at least if moving towards a different point of actuality does not entail that it stops persisting through time. More generally, in a 5D framework coincidence-free, local dynamical theories of wormhole travelling seem *in principle* formulable. Yet, does it free it from the global constraint altogether?

matter: for my purposes a difficulty arises insofar as someone can leave a point of actuality at a temporal coordinate t' and "then" reach a different point of actuality at a preceding temporal coordinate *t*.

[14] Of course, in so far as it is an empirical issue whether we inhabit a 5D manifold or not, dialectical considerations can be overridden by experimentally corroborated theories.

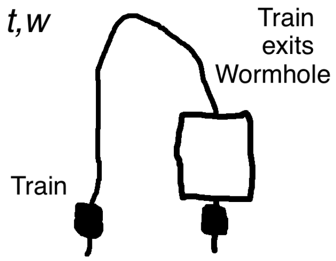

Fig. 10

It is crucial to notice here that what is “global” in a 4D manifold is different from what is “global” in a 5D embedding of it. More precisely, in a 5D situation, the regions of reality that count as “global” should also extend to the regions that we find along the actuality dimension. Consider the situation in Fig. 10, where the train exits the wormhole at *t* in *w*.

If the train enters the wormhole at *t'* in *w*, it cannot have exited the wormhole at *t* in *w*, even in a 5D manifold. The scenario constrains the goings-on of the train in such a way that if it has entered the wormhole at t' in *w*, it cannot exit it at *t* in *w*, but it has to “deviate” to w' perforce. But what makes w' at *t* so different from *w* at *t*? Fig. 10 depicts a situation that cannot take place, *if* what is depicted in Fig. 7 happens (that is, in *w* the train enters the wormhole at t'), but which locally would be as physically possible as the situation in Fig. 12. In so far as we can assume that the situations in Figs. 8 and 10 would be qualitatively indistinguishable, the only answer can be in how they connect with other points of actuality and other times. Does this mean that only a *global* constraint can explain why the train in a 5D manifold will end up in w' rather than in *w* – namely that the explanation of the whereabouts of the train are no less coincidence-free in a 5D manifold than in a 4D one? The answer is yes, *unless* there is a local dynamical theory that can provide us with an explanation of why the train will be “pushed” towards w' rather than *w*, given what we find in the area of actuality before the train enters the wormhole (what is depicted in Fig.7).

Unfortunately, a local explanation of why the train has to “deviate” along actuality does not seem forthcoming. Indeed, it is not difficult to imagine situation in which “coincidences” will show up also in a 5D scenario. Imagine we have a local dynamical theory that tell us that whether the train will be “pushed” towards w' or *w* depends on some of its intrinsic states. Let’s say that if the train is positively charged the wormhole takes it to *w*, while if it is negatively charged the wormhole takes it to w'. It is surely locally possible to construct a device such that if it does not detect a train outside a tunnel at time t it becomes positively charged and heads towards the entrance of a tunnel. Yet, if the tunnel is a wormhole *at point w of a 5D manifold*, which leads positively charged objects that enter it at t' to point w at t, and negatively objects that enter it at t' to point w' at t, something will prevent the train from becoming positively charged (or from entering the tunnel at all). And there is nothing that locally explains why this will be so. It is only globally — by endorsing the perspective from the whole 5D manifold — that we can explain why the train cannot become positively charged. Given that the local dynamical theory cannot provide an explanation of why the device won't work properly, we have to conclude that there are "coincidences" in a 5D manifold too. The global configuration of the 5D manifold can tell us only that *something* will impede the device from working properly, but not what kind of events will be locally responsible for this[15].

Surely there can be ways to specify the dynamical theory that guarantee that an entity that enters a backwards directed wormhole will always end up at a certain distance from the point of actuality from which it started. A theory of this sort would respect AUTONOMY. However, this would be a pyrrhic victory for the defender of a 5D manifold. The fact that such a scenario is coincidence-free is entirely due to the presence of a "current" in a flat actuality space (or some equivalent factor). It is not the hypothesis *per se* that reality is a 5D manifold that explains the lack of coincidences. Compare the situation with one in which the dynamical theory constrains a time traveler in a 4D manifold to end up invariably very far away (spatially and temporally) from its point of departure. Such a theory would be coincidence-free, but merely because of the constraint that it incorporates – at any rate, surely not in virtue of the structure of the 4D manifold on which it is specified! Moreover, a defender of the 5D manifold should *independently* motivate the choice of an actuality dynamics of this sort. And, as we notice already, given our present knowledge no such a justification seems forthcoming.

The moral is that *if* TIME-TRAVEL is incompatible with AUTONOMY in a 4D space-time manifold where UNITY holds, then adding a degree of freedom by embedding the 4D manifold in a 5D space-time-actuality manifold won't really vindicate AUTONOMY. The best that the 5D manifold solution to the puzzles of time travel can do is to save a

[15] Besides, there could be ways of concatenating events at different actuality points together, so that even if an object doesn't arrive in the past of the same actuality from which it departed, some counterpart of it is guaranteed to do so. Thanks to an anonymous referee for suggesting this further scenario.

version of AUTONOMY that is relativized to points of actuality. If the global constraints are "global" only relative to points of actuality, then nothing globally (in this sense) will constrain what is possible for the train locally. As in Fig.6, Fig.7, and Fig.8, the train can enter the tunnel at t' after it has not detected a train coming out of the tunnel at t, and end up at point w' of actuality at time t. But an "unrestricted" version of AUTONOMY cannot be vindicated. As the examples above show, there are locally possible situations in a 5D manifold, which are ruled out by global consistency constraints, once TIME-TRAVEL is on board. Thus, if AUTONOMY is violated by traveling back along the temporal dimension in a four-dimensional manifold, then it is also violated in a five-dimensional manifold (and presumably in any n-dimensional one). Given that TIME-TRAVEL is a live option in contemporary physics, Lewis's "coincidence" solution to the time travel puzzles is dialectically still the best one on the market[16].

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