

Article

Exterminous Hypertime

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Abstract: This paper investigates ‘exterminous hypertime’, a model of time travel in which time travellers can change the past in virtue of there being two dimensions of time. This paper has three parts. Part one discusses the laws which might govern the connection between different ‘hypertimes’, showing that there are no problems with overdetermination. Part two examines a set of laws that mean changes to history take a period of hypertime to propagate through to the present. Those laws are of interest because: (i) at such worlds, a particular problem for non-Ludovician time travel (‘the multiple time travellers’ problem) is avoided; and (ii) they allow us to make sense of certain fictional narratives. Part three discusses how to understand expectations and rational decision making in a world with two dimensions of time. I end with an appendix discussing how the different theories in the metaphysics of time (e.g., tensed/tenseless theories and presentism/eternalism/growing block theory) marry up with exterminous hypertime.

Keywords: time travel; exterminous hypertime; hypertime; non-Ludovician; growing block theory; eternalism; presentism; overdetermination; truth in fiction



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Imagine I time travel from 2021 to 1930 and assassinate Hitler. For this to be possible, a ‘non-Ludovician’ model of time travel must be true. One such model is ‘exterminous hypertime’ whereby the changes are possible because time has two dimensions. This paper examines that model, expanding on previous papers of mine on the topic [1] (pp. 73–90) [2]. (Note that this ‘hypertemporal theory’ is not the same as that discussed by Goddu [3–5], van Inwagen [6], and Wasserman [7] (pp. 90–94); for a discussion of the differences, see [1] (pp. 76–90) and note 4).

After an initial exposition of the theory (Section 1), this paper proceeds in three parts. Part one considers the causal links between hypertimes, what I call ‘hypercausation’ (Section 2). As Section 3 explains, contrary to the likes of Smith [8] (and my earlier self [1] (pp. 83–84)), exterminous hypertime has no problem concerning overdetermination.

This paper does *not* argue that our world is *actually* one of exterminous hypertime—after all, for all I know time travel is not even physically possible¹. Rather, this paper is an exploration only of what is metaphysically possible.

You might wonder what the point of such an exploration is. In Section 4, I examine different possible laws which might govern exterminous hypertemporal worlds. To show why those laws are of interest, Section 5 discusses two applications. Firstly, time travellers in exterminous hypertemporal worlds avoid an obstacle to time travel that threatens certain alternative non-Ludovician theories. Secondly, it allows us to make sense of certain fictional stories that are *prima facie* metaphysically impossible. That completes the second part of this paper.

In the third and final part, which follows from the discussion about how to understand what agents in fictional stories say and do, I discuss how to understand expectation and rational decision making in a world with two dimensions of time (Section 6). I argue that agents are rational in worrying about the hyperfuture and rational to accordingly change how they act in light of what might hyperlater happen.

This paper ends with an appendix on how exterminous hypertime connects with various issues in the metaphysics of time, namely tensed vs. tenseless time, the ontology of time, and the open future.

1. The Basic Theory

1.1. Two Dimensional Time

Exterminous hypertemporal worlds have multiple dimensions of time. In this paper, I assume such worlds have just the two (elsewhere, though, I have discussed versions of the theory with three or more [2]).

To better understand exterminous hypertime's multiple dimensions of time, compare them to the multiple dimensions of space. Space has three dimensions. Pictorial representations of space correspondingly have three axes, the x , y , and z axes. We can similarly represent two temporal dimensions with two axes, one being the regular temporal axis and the other being the hypertemporal axis. The x , y , and z axes of a spatial diagram are such that every point along the x axis exists at every point along the y and z axes (and every y point exists at every point along the x and z axes, and similarly for every z point). The same applies to exterminous hypertime. At every different hypertime, the entire complement of times exist. Use $t_1, t_2 \dots$ to name different instants of regular time (where t_n names an arbitrarily selected instant from n AD). Use $T_1, T_2 \dots$ to name different instants of hypertime. At T_1 , every time exists, i.e., $t_1, t_2 \dots$ all exist at T_1 . At T_2 , every time also exists, i.e., $t_1, t_2 \dots$ all exist at T_2 . And so on, for every hypertime.

Use the following notation to pick out different points of time-hypertime: ' t_n-T_m ' picks out time t_n at hypertime T_m , e.g., $t_{1930}-T_1$ picks out an instant from 1930 at hypertime T_1 whilst $t_{2021}-T_{14}$ picks out an instant from 2021 at hypertime T_{14} .

1.2. Time Travel

I have previously argued [1] (p. 77) [2] that this two-dimensional picture of time can be used to understand time travel, as have others [7,9] (pp. 98–99) (see also [10]). This subsection summarises how this works.

Imagine I use a time machine to travel from 2021 to 1930 and successfully kill Hitler, preventing World War II. Exterminous hypertime can make sense of this scenario if we assume:

PROGRESSION: For any hypertime T_j , any regular time t_n , and any time traveller, x : if, at T_j , x time travels from t_n to $t_{m < n}$ then x travels to $t_{m < n}-T_{j+1}$ ^{2,3}.

Given PROGRESSION, time travellers move progressively forwards in hypertime. They can travel back in regular time, but never back in hypertime. When I kill Hitler, I start at (e.g.,) hypertime T_1 . At T_1 , in 2021, I activate my time machine and travel back to 1930. Given PROGRESSION, I leave T_1 and travel to hypertime T_2 , arriving in the past in 1930. That is: I leave $t_{2021}-T_1$ and travel to $t_{1930}-T_2$. At T_1 , history is such that Hitler survived 1930 and World War II started in 1939, i.e., Hitler is alive at $t_{1930}-T_1$ and war breaks out at $t_{1939}-T_1$. At T_2 , history is different because I have assassinated Hitler. Having killed Hitler in 1930, he is dead at $t_{1930}-T_2$. This further prevents the outbreak of war, ensuring $t_{1939}-T_2$ is peaceful and harmonious. See Figure 1.

This theory is not without its problems. Questions include: What is hypertime exactly? Even though space can have multiple dimensions, is it not mind-boggling to think time can likewise have multiple dimensions? [7] (p. 99) [11] (p. 9) [12] (p. 209). Are the people at other hypertimes just *duplicates* of people at hyperearlier hypertimes—that is, do I not just end up killing a duplicate of Hitler when I kill the 'Hitler looking person' at $t_{1930}-T_2$? [13]. Is it accurate to call my making T_2 different from T_1 a case of 'changing the past'? [14,15] (p. 152) [16] (pp. 365–366) (see also [5]).

These are all good questions. However, I have dealt with them elsewhere [1] (pp. 79–90) and they are not the subject of this paper. Instead, this paper focuses on questions concerning the causal connections between the hypertimes.

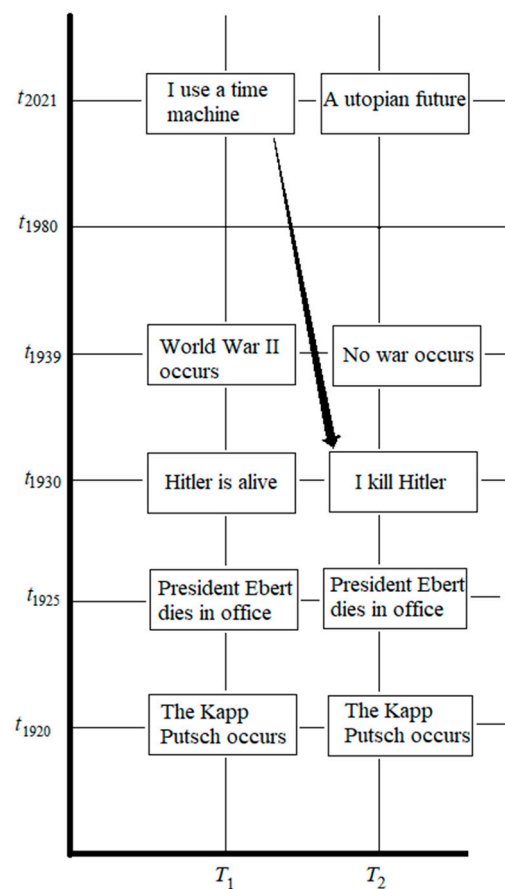


Figure 1. Exterminous hypertime and time travel.

2. Hypercausation

2.1. Stability

Not every world with multiple temporal dimensions is a world of exterminous hypertime. Both philosophers ([17,18] (p. 278) [19–22] (pp. 30–34) [23] (pp. 46–49) [24–26] (pp. 20–27) [27,28]) and physicists [29–35] have discussed worlds with multiple temporal dimensions, but such worlds are not anything like those discussed in this paper. More things must therefore be true to characterise worlds of exterminous hypertime. PROGRESSION is one such example. Another example would be:

STABILITY: For all n and m , and for some j and k : t_n-T_m is qualitatively identical to t_n-T_{m-1} except when a time traveller from $t_{j \geq n}-T_{m-1}$ has time travelled to $t_{k \leq n}-T_m$.

STABILITY ensures that the past does not change except when time travel occurs—left unmolested by time travellers, the past is always the same as it was at the immediate hyperearlier hyperinstant. For instance, at a world where no time travel takes place, then STABILITY entails that t_{1930} is the same at every hypertime, as is t_{2021} , and, indeed, all times (see Figure 2); whereas, in a world where time travel takes place, time-hypertimes may differ, but only if they are later in time than the arrival of some time traveller from a hyperearlier hypertime. Look back at Figure 1: every instant prior to t_{1930} is the same at T_1 and T_2 , and it is only after my arrival at $t_{1930}-T_2$ that the time-hypertimes differ because I have killed Hitler.

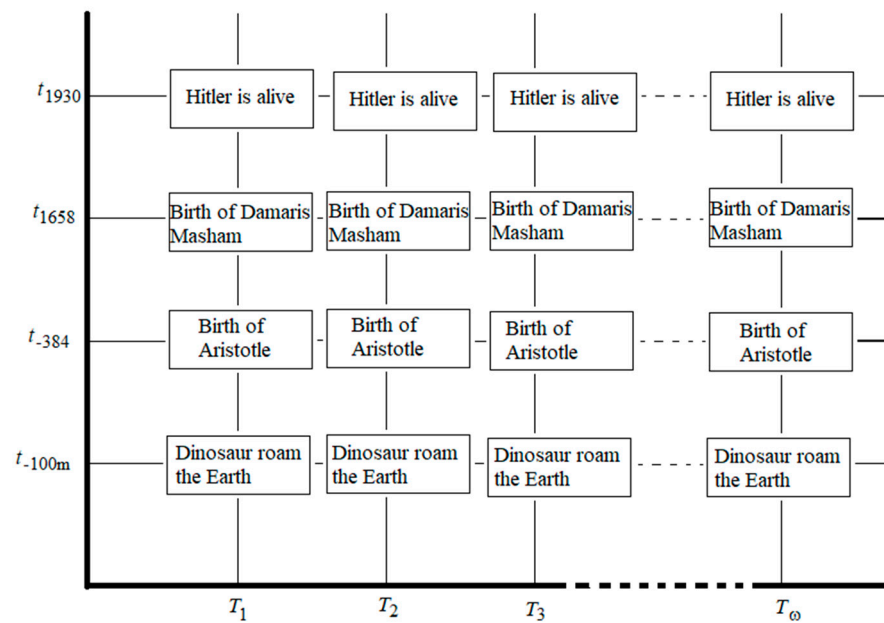


Figure 2. An exterminous hypertemporal world with no time travel.

STABILITY is important. In a one-dimensional temporal world, later times are suitably similar to earlier times. It is only via causal activity that the later times differ from the earlier times. STABILITY is one way of ensuring that a similar claim is true of hypertime. Given STABILITY, hyperlater hypertimes differ from hyperearlier hypertimes only because of the causal activity of time travellers.

Indeed, without STABILITY, it would be hard to recognise moving to hyperfuture hypertimes as being a form of time travel. Imagine STABILITY was false. Given it is false, historical events can play out differently at the different hypertimes, independently of how the world hyperearlier was. Imagine that: at T_1 , history as we know it plays out; at T_2 , the Big Bang is instead a Small Splutter and for all eternity the universe is an empty void; at T_3 , the Big Bang occurs but history plays out differently and, by 2021, squid-headed aliens rule a universe composed of planets and galaxies foreign to those found at T_1 . At T_1 , in 2021 I build a time machine. I gather together my friends and, intending to amaze them, I travel back in time twenty seconds. Rather than appearing in the past surrounded by my companions watching me step into my time machine, I appear at T_2 in the empty void of space. Confused, I then decide to head back to 1930 to kill Hitler. I appear at T_3 , surprised to find myself at the mercy of cephalopodic monsters who live in a galaxy that did not even exist when I was younger. Fantastic things are happening when I activate my machine, but travelling back in time does not seem to be one of them. Twenty seconds ago, the past was full of material objects, so how can I have travelled back twenty seconds if the place I arrive at it is devoid of all matter? Ninety one years ago, the Weimar Republic existed, so how can I have arrived in 1930 if the Weimar Republic is instead nowhere to be found? In an unstable world, movement between hypertimes does not seem to give rise to what we would normally think of as ‘time travel’ [36] (pp. 379–380). Given STABILITY, this problem is avoided. Hence, we should endorse STABILITY.

2.2. Explaining Stability

Whilst STABILITY might be inexplicably true, it is less strange to think that certain laws of nature will explain it. The rest of this paper assumes that STABILITY is true because certain hyperearlier time-hypertimes stand in a causal relation to other hyperlater time-hypertimes. Dub that causal connection ‘hypercausation’. (Note that hypercausation is not a ‘metaphysically different’ type of causation; the introduction of the term is solely for the purpose of exposition.)

Given such hypercausal connections, we can explain STABILITY. When I travel back to t_{1930-T_2} , that time-hypertime is such that Hitler is alive (and the Weimar Republic is running Germany, etc.) because the immediately hyperprior time-hypertime (i.e., t_{1930-T_1}) hypercausally influences t_{1930-T_2} in a way that makes it almost entirely qualitatively identical to t_{1930-T_1} , differing only with regard to my arrival in a time machine.

3. Overdetermination

Some people have worried that there being hypercausal connections between time-hypertimes gives rise to a problem of systematic overdetermination. Section 3.1 explains the worry. Section 3.2 argues that, even if there were systematic overdetermination, it is not worrying. Section 3.3 argues that, in any case, we need not believe that there is such systematic overdetermination in the first place.

3.1. The Threat of Overdetermination

An event may be a ‘partial’ cause of its effect or a ‘whole’ cause. For example, if three people lift a table then each person’s lifting is a partial cause of the table being lifted. It is only their collective action that wholly causes the lifting.

Given that causation is transitive, effects can have multiple whole causes. If e_1 wholly causes e_2 which in turn wholly causes e_3 , then e_1 and e_2 are both whole causes of e_3 . Such cases are routine and occur all of the time. But some cases of effects having multiple whole causes are weirder. In the routine cases (e.g., of e_1 and e_2 causing e_3) we can trace a single chain of causes threading all three events. In the weird cases, an effect has multiple whole causes from *separate* causal chains. For instance, imagine two assassins independently, yet simultaneously, kill a target, e.g., an assassin’s bullet strikes the victim in the heart at exactly the same moment that the second assassin’s poison causes a terminal encephalopathic event. This is weird in a way that the chain of e_1 , e_2 , and e_3 is not weird. Call the weird cases ‘overdetermination cases’.

Whilst weird, overdetermination cases are possible. Yet, we tend to think they do not *regularly* take place, i.e., we think *systematic* overdetermination is not taking place. (As a forewarning, Section 3.2 questions exactly this assumption). If STABILITY is explained hypercausally, then there is at least a *prima facie* reason to think systematic overdetermination will be a problem—a worry previously noted by both Smith [8] (pp. 691–692) and myself [1] (pp. 83–84).

To see why we might suspect that there is systematic overdetermination, imagine a world at which there is no time travel and consider the 1804 liberation of Haiti. At t_{1804-T_1} , the self-liberated slaves have finally overthrown French rule. Assuming there is no hypertime prior to T_1 , t_{1804-T_1} is the way it is solely because, at earlier (regular!) times at T_1 , the slaves did things to cause the liberation at t_{1804-T_1} . Since t_{1804-T_2} is qualitatively identical to t_{1804-T_1} (since all earlier times at T_2 are qualitatively identical to the earlier times from T_1), the liberation of Haiti at t_{1804-T_2} is likewise wholly caused by the actions of slaves from earlier times at T_2 . However, given the hypercausal explanation of STABILITY, the liberation of Haiti at t_{1804-T_1} *also* wholly causes the liberation of Haiti at t_{1804-T_2} . We have a case of overdetermination! And what goes for the liberation of Haiti goes for every event at every hypertime other than T_1 . So, at such a world, there is systematic overdetermination. Given the assumption that there is no systematic overdetermination, exterminous hypertime would have a problem⁴.

3.2. There Is No Problem of Overdetermination

However, this is much too quick. Firstly, as already noted, overdetermination cases are possible, even if they are unlikely. An anonymous referee (for my monograph [1], not this paper) correctly pointed out that these worries about systematic overdetermination only show that we probably do not *actually* live in an exterminous hypertemporal world. Since this paper is interested only in what is possible—and readily admits that we do not actually

live in an exterminous hypertemporal world—then worries about overdetermination are by-the-by.

Secondly, if the problem of systematic overdetermination is that it is unlikely, then it is not a problem in any case⁵. When we say systematic overdetermination is ‘unlikely’, the type of likelihood in question is ‘objective chance’. Objective chance is intimately tied up with the laws of nature. However, at a world of exterminous hypertime, the systematic overdetermination is *mandated* by the laws of nature (see Section 4 for examples of such mandating laws). Since it is mandated, the overdetermination is therefore *not* unlikely. Indeed, since the laws mandate it, it always has a chance of occurring equal to 1—the overdetermination is *as likely as it could possibly be*. The liberation of Haiti at $t_{1804}-T_2$ may be wholly caused by two distinct events, but it is no coincidence! Thus, even if there is systematic overdetermination, it is not of the problematic kind⁶.

One objection might be that the *laws themselves* are unlikely, i.e., it is unlikely to find oneself in a world with laws mandating systematic overdetermination. However, whilst debating the objective chance of an event given certain laws is straightforward, discussing the likelihood of the laws themselves is not. We are immediately dragged into the quagmire of issues involved in the fine-tuning debate (see, e.g., [37,38] (pp. 147–154) and [39]). Since this objection quickly becomes stuck on such issues, I set it aside.

3.3. Exterminous Hypertemporal Worlds Need Not Be Worlds of Systematic Overdetermination

Section 3.2 argued that if an exterminous hypertemporal world contained systematic overdetermination then we need not worry. This section argues that we do not even need to go that far, because we need not think that exterminous hypertemporal worlds feature systematic overdetermination in the first place.

Introduce another chance function alongside the objective chance function. Call it the ‘counterhypercausal chance function’—or ‘chance_{chc}’, for short. The chance_{chc} of an event occurring (at some time t) is the objective chance it would have of occurring (at t) if only nothing hypercausally interfered with it. As an example, consider the following case:

Case one: Moscovium decay with no time travel. At $t_{2021}-T_1$ a moscovium atom has 0.5 chance of decaying a few milliseconds later. And, indeed, it decays. Further, no time travel takes place at this world. At $t_{2021}-T_2$, consider the same atom. Since no time travel has occurred, it has a chance_{chc} of decaying equal to 0.5. However, given Stability it must decay, so at $t_{2021}-T_2$ it has a chance of decaying equal to 1⁷.

This in place, turn back to how a world of exterminous hypertime can avoid systematic overdetermination. The key is to assume that a time-hypertime hypercausally influences another time-hypertime *only* regarding probabilistic events, i.e., events not determined to happen. In such cases, the hypercausal interaction either ensures that the event happens (if it occurred at the hyperprevious time-hypertime) or ensures that the event does not happen (if it did not occur).

Return to the Haiti example. Imagine that the laws of nature are such that the actions of the self-liberated slaves at $t_{1803}-T_2$ determine most of what goes on at $t_{1804}-T_2$, i.e., most events at $t_{1804}-T_2$ are non-probabilistic. At $t_{1803}-T_2$, the remaining events at $t_{1804}-T_2$ have a chance_{chc} of occurring between 0 and 1. It is those remaining events (and only those events) that are influenced by hypercausation. Thus, the earlier events of $t_{1803}-T_2$ are only a partial, not whole, cause of the liberation of Haiti. Similarly, the events of $t_{1804}-T_1$ are only a partial, not whole, cause of the liberation at $t_{1804}-T_2$. It is only the *conjunction* of these things that is the *whole* cause. Therefore, there is no overdetermination (and so no systematic overdetermination) because overdetermination involves distinct *whole* causes bringing about some effect, not distinct *partial* causes bringing about some effect. Problem solved.

4. Hypercausal Laws

This section examines the different hypercausal laws that would allow for a world of exterminous hypertime. Sections 2 and 3 have argued that all such laws must entail STABILITY; however, there are other dimensions along which they may vary.

4.1. Local vs. Global

The first possible hypercausal law for consideration is:

GLOBAL EFFECT: For any event, e , and all j, k, m and n , if e occurred at t_m-T_{n-1} then whether or not it occurs at hyperlater hypertimes depends upon whether a time traveller has (or has not) time travelled from $t_{j \geq m}-T_{n-1}$ to $t_{k \leq m}-T_n$:

If a time traveller has *not* time travelled from $t_{j \geq m}-T_{n-1}$ to $t_{k \leq m}-T_n$ then e occurs iff it occurred at t_m-T_{n-1} (except where t_m-T_{n-1} does not exist—i.e., where T_n is the first hypertime—in which case e has a chance of occurring equal to its chance_{chc} of occurring).

If a time traveller *has* time travelled from $t_{j \geq m}-T_{n-1}$ to $t_{k \leq m}-T_n$ then e may or may not have occurred. Its occurrence will be probabilistically governed; the chance (at t_l-T_n , for all $l < m$) of e occurring is equal to its chance_{chc} of occurring⁸.

Given GLOBAL EFFECT, time-hypertimes are qualitatively identical to their immediately hyperprevious-yet-simultaneous time-hypertimes unless someone has time travelled to that time or earlier. And if a time traveller has travelled to that time or earlier, then all hypercausal ties are severed—from that point forwards, ‘all bets are off’ when it comes to how the future can play out, with no hypercausation affecting matters.

To see the upshot of GLOBAL EFFECT, consider four example cases. Start with Case One from above. In Case One, the moscovium atom decayed just after $t_{2021}-T_1$. Since there is no time travel in Case One, GLOBAL EFFECT entails that it also decays just after $t_{2021}-T_2$ (Which is just as it should be, because this is just what STABILITY requires).

Next, consider:

Case Two: Moscovium decay with time travel and interaction. As per Case One, but a time traveller from $t_{3000}-T_1$ has time travelled to T_2 to an instant a few hours earlier than t_{2021} . There, the time traveller accelerates the moscovium atom to close to the speed of light, lowering its chance_{chc} of decaying from 0.5 to 0.1.

Given GLOBAL EFFECT, because the time traveller has arrived at a time earlier than $t_{2021}-T_2$, the chance (at $t_{2021}-T_2$) of the atom decaying a few milliseconds after $t_{2021}-T_2$ ends up being independent of the hyperprior hypertime, i.e., the chance is 0.1 (rather than, as in Case One, a chance of 1). So, it may very well *not* decay, quite unlike with Case One.

Case Three: Moscovium decay with time travel but no interaction. As per Case Two, but the time traveller does not interact with the moscovium atom (for instance, because they arrive on the other side of the world).

Even though the time traveller does not interact with the moscovium atom, given GLOBAL EFFECT, the hyperearlier time-hypertime nevertheless no longer hypercausally affects $t_{2021}-T_2$. That means that (at $t_{2021}-T_2$) the chance of the atom decaying is 0.5; at $t_{2021}-T_2$ the moscovium is as liable to decay as not.

Finally, consider:

Case Four: The Andromeda case. At $t_{2021}-T_1$ there exists a time portal. Stepping through it, you travel to the Andromeda galaxy in 50,000 BC. Staying for a few minutes, you then use the portal to return back to the future on Earth. Obviously, what you do in Andromeda’s Palaeolithic past does not affect events on the planet Earth in its history leading up to the present day.

Given GLOBAL EFFECT, you will almost certainly find history has played out differently. Imagine that an ancestor of Aristotle from 40,999 BC did not die of cancer before

reaching child-bearing age at T_1 because of an unlikely stochastic event. At T_2 , your arrival in Andromeda means that the ancestor's survival is again put in doubt. Imagine that what is most likely happens and the ancestor *does* die. Resultantly, Alexander the Great fails to learn the correct lessons from Aristotle, never defeats the Achaemenid Empire, and history is radically changed. Even though you spent only a minute or two in the Andromeda galaxy, when you return through the time portal to 2021, you find that the world is now under the control of the Neopersian Hegemony. Everyone you know has gone; your ancestors of the previous thousands of years never existed; Earth's history is nothing like that which you remember.

So, as Case Three and Case Four make clear, GLOBAL EFFECT means that *any* time travel interferes with history on a universal scale. Even things far removed from a time traveller can be affected by their act of time travel.

GLOBAL EFFECT is not the only possible law that there might be at a world of exterminous hypertime. Consider:

LOCAL EFFECT: For any event e , and all m , n and k , whether an event e occurs at $t_m - T_n$ depends upon whether someone has or has not time travelled from $t_{j \geq m - T_{n-1}}$ to $t_{k \leq m - T_n}$:

If a time traveller has *not* time travelled from $t_{j \geq m - T_{n-1}}$ to $t_{k \leq m - T_n}$ then e occurs iff it occurred at $t_m - T_{n-1}$ (except where $t_m - T_{n-1}$ does not exist—i.e., where T_n is the first hypertime—in which case e has a chance of occurring equal to its chance_{chc} of occurring).

If some time traveller *has* time travelled from $t_{j \geq m - T_{n-1}}$ to $t_{k \leq m - T_n}$ then e 's occurring or not depends upon whether some time traveller has causally interacted/influenced any factors governing e 's occurring or not. If some such factor has been influenced by a time traveller, then e 's occurring is now independent of what went on at the hyperearlier time-hypertime; e 's chance of occurring is equal to its chance_{chc} of occurring. If some such factor has not been influenced by a time traveller (e.g., the time traveller arrived too spatiotemporally distant to influence e 's coming about or not) then e occurs iff it occurred at $t_m - T_{n-1}$.

To see the difference between LOCAL EFFECT and GLOBAL EFFECT, reconsider the cases. Cases One and Two play out exactly as they do given GLOBAL EFFECT. However, in Cases Three and Four, LOCAL EFFECT and GLOBAL EFFECT diverge. Consider Case Three. Arriving in the past, the time traveller does not causally interact with the moscovium atom. Given the second clause of LOCAL EFFECT, e must therefore occur, contrary to what was true given GLOBAL EFFECT. Similar thoughts apply to Case Four. Arriving in Andromeda, the time travellers cannot causally influence events in the Milky Way. Hence, events in Earth's past are still held tight in the grip of hypercausation, playing out exactly as they did at T_1 . Given LOCAL EFFECT, when the time travellers return to the future, they find everything exactly as it was before.

So exterminous hypertime might allow for time travel having a local or global influence. If it is global, then as soon as a time traveller arrives in the past, the entire universe's future is unshackled from slavishly following the course of the previous hypertime. If it is local, only those events that the time traveller interacts with can turn out differently from the previous hypertime.

4.2. Propagative Laws

The local/global dimension is not the only dimension which the laws of nature can vary over. Both LOCAL EFFECT and GLOBAL EFFECT have it that when the future is changed, it is changed 'hyperinstantaneously', i.e., when a time traveller intercedes in history, the very next hyperinstant is such that the entire future reflects the changes that have been made. However, we might instead believe that the changes to history 'propagate', taking a period of hypertime to change the future. That is: A time traveller changes the past, but at

the next hyperinstant those changes are only reflected at a tiny bit of history; as hypertime moves on, more and more of history changes to reflect the time traveller's actions.

As an initial example, imagine that I go back and kill Hitler. If changes propagate, then the next hyperinstant of hypertime will not reflect that change. Even though, at the next hyperinstant, I killed Hitler in 1930, he is still alive in 1939 and starting World War II. We have to wait until a hyperlater hypertime for history to have changed such that Hitler is now dead in 1939 and World War II does not occur. That is: The changes caused by time travellers propagate over a *hypertemporal* period.

This subsection details the laws required to make exterminous hypertime 'propagative'. (I will assume throughout that time travel has a global influence, similar to GLOBAL EFFECT, though I see no reason to think that a local version, riffing off of LOCAL EFFECT, could not instead be constructed).

First, we must say that there is a property of 'hyper-resilience'. It is had (or not) by time-hypertimes. Three hypercausal laws govern hyper-resilience:

1. For all j and k , t_j-T_k is *not* hyper-resilient iff something tried to causally influence t_j-T_{k-1} that did not try to causally influence t_j-T_{k-2} ; otherwise, t_j-T_k is hyper-resilient.
2. For all j and k , if t_j-T_k is hyper-resilient then events occur at it iff they occurred at t_j-T_{k-1} . This is the case even if something (e.g., a time traveller coming from the previous hypertime) tries to causally influence them to be otherwise, i.e., hyper-resilience 'trumps' all other forms of causal force and activity.
3. If a time-hypertime is *not* hyper-resilient then there is no hypercausal influence between its hyperprior time-hypertime and it. What goes on at such time-hypertimes is governed only by what went on at hypersimultaneous earlier times in combination with the causal influence of any time traveller who has arrived from the hyperprevious hypertime.

Call the conjunction of these claims GLOBAL PROPAGATION. If GLOBAL PROPAGATION is a law of nature, then changes to history take a period of hypertime to issue forth through to the present. Consider how killing Hitler would pan out given GLOBAL PROPAGATION. Figure 3 depicts what would happen: time-hypertimes are depicted as the larger boxes; whether or not they are hyper-resilient is represented by a tic/cross in the smaller box, where a tic represents that the time-hypertime is hyper-resilient and a cross indicates that it is not. In accord with law (1), every time-hypertime at T_1 is hyper-resilient. At T_1 I attempt to travel from T_1 to 1930 to kill Hitler. Given law (1), every time-hypertime at T_2 is also hyper-resilient. So, given (2), every time-hypertime at T_2 is the same as it was at T_1 ; since I was not in 1930 at T_1 then, even though I *try* to travel to $t_{1930}-T_2$, the hyper-resilience of $t_{1930}-T_2$ trumps my attempt; thus, I do not appear at $t_{1930}-T_2$. However, no time traveller tried to causally interact with $t_{1930}-T_1$ by trying to arrive there, whilst a time traveller *does* try and causally interact with $t_{1930}-T_2$ by trying to arrive there. So, given (1), $t_{1930}-T_3$ is *not* hyper-resilient. Since it is not hyper-resilient then, given (3), events at $t_{1930}-T_3$ can play out differently than $t_{1930}-T_2$. So, whilst I do not arrive at $t_{1930}-T_2$ from $t_{1930}-T_1$, I *do* arrive at $t_{1930}-T_3$ (having arrived there from $t_{2021}-T_2$). However, I fail to persist any further at T_3 . This is because the next time-hypertime in T_3 , call it $t_{1930+\delta}-T_3$, is hyper-resilient; given (2), it must be qualitatively identical to $t_{1930+\delta}-T_2$; since I did not exist at $t_{1930+\delta}-T_2$, then I do not exist at $t_{1930+\delta}-T_3$ either. However, because something tries to causally affect $t_{1930+\delta}-T_3$ that did not try to causally affect $t_{1930+\delta}-T_2$, $t_{1930+\delta}-T_4$ is *not* hyper-resilient. So, I arrive at $t_{1930}-T_4$ and *can* persist to $t_{1930+\delta}-T_4$. I cannot, however, persist to the instant after that. At T_5 , the same reasoning means that I can manage to persist to the instant after, but no further. At T_6 , similar reasoning dictates that I manage to persist one instant more. And so on. Ultimately, we arrive at a hyperinstant, T_ω , where my interaction with the past has hyperfinally influenced the future, stopping World War II and bringing about a utopian future⁹.

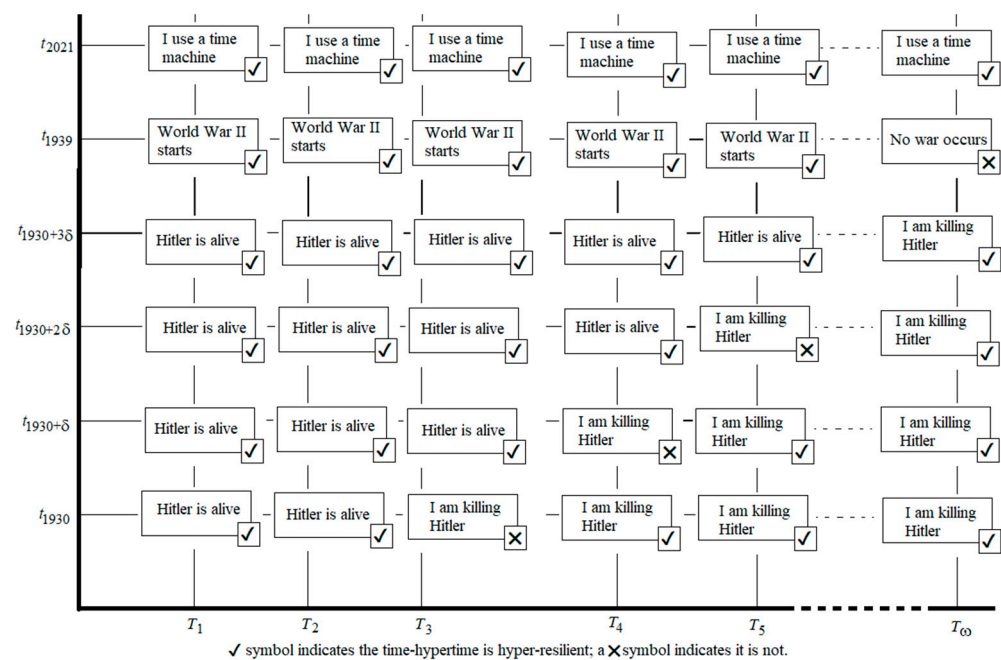


Figure 3. A globally propagative time travel scenario.

5. Applications of Global Propagation

You might wonder why I care about worlds at which GLOBAL PROPAGATION is true. After all, lots of weird things are metaphysically possible, so why be interested in *this* weird possibility? This section explains two interesting features of propagative worlds.

5.1. The Multiple Time Travellers Problem

Some theories that allow for the past to change face the ‘Multiple Time Travellers Problem’. Versions of this problem have been discussed by Hudson and Wasserman [9] (p. 42) (see also [7] (p. 96 n. 73) as well as myself [36,40]. This section details that problem and then explains how GLOBAL PROPAGATION avoids it.

Start by imagining that changes to the past do *not* propagate through to the future and that GLOBAL EFFECT is true. At $t_{2021}-T_1$ I decide to travel to the past to kill Hitler. However, Malcolm—who is at $t_{2022}-T_1$ —also uses a time machine. Malcolm travels to 50,000 BC (at T_2), kills Aristotle’s ancestor, and brings about the NeoPersian Hegemony. Given PROGRESSION, we both arrive at T_2 (albeit at different times: me arriving in 1930 and Malcolm arriving in 50,000 BC). At $t_{1930}-T_2$, I arrive and expect to find Hitler and Germany but, because of Malcolm’s interference, I instead find that Germany, Hitler, and all of Hitler’s ancestors for a thousand generations never existed. As discussed in Section 2.1, if a putative time traveller arrives in the past and does not find such things, that is problematic because they do not appear to really have a time machine. So we have a problem. Call it the ‘Multiple Time Travellers Problem’: At a world where GLOBAL EFFECT is true, if multiple time travellers go back to the past, only those time travellers arriving at the earliest moment manage to succeed; everyone else arrives somewhere which is not properly seen as being ‘their past’ and so fails to travel in time.

GLOBAL PROPAGATION avoids this problem¹⁰. In a world where GLOBAL PROPAGATION is true, neither myself nor Malcolm arrive at T_2 . However, we do arrive at T_3 , if only for an instant. Malcolm’s actions at $t_{-50,000}-T_3$ do not have any causal effect on events in the (regular) future, so when I arrive at $t_{1930}-T_3$, it is exactly as I expect it to be, i.e., with Germany, the Weimar Republic, and Hitler all in existence. So I *do* arrive somewhere properly called ‘the past’. Thus, I manage to travel in time even though Malcolm *also* manages to travel in time.

As hypertime moves on, more and more of the past will be affected by our changes. For instance, there will be a hypertime, T_ω , at which ten years of time apiece have been ‘affected’. At T_ω :

- 50,000 BC–49,990 BC include Malcolm’s arrival in the past and the changes he has made;
- 49,990 BC–1930 AD are just as they are at T_1 (i.e., with no Malcolm at them, nor affected by anything Malcolm did at 49,990 BC or earlier);
- 1930 AD–1940 AD include my arrival in the past, assassinating Hitler, and preventing World War II;
- 1940 AD onwards is exactly as it originally was at T_1 , i.e., Hitler is alive, World War II is taking place, etc.

If we hyperwait long enough, then we get to a hyperlater hypertime, $T_{\omega'}$, where Malcolm’s interaction with the past finally catches up to 1930. At $T_{\omega'}$, I arrive in 1930 (having come from $t_{2021}-T_{\omega'-1}$) and am bewildered to find Germany has gone, the Weimar Republic does not exist, Hitler was never born, etc., and all such things have been replaced by the NeoPersian Hegemony. In that case I have *not* time travelled from $T_{\omega'-1}$ to $T_{\omega'}$. Nevertheless, GLOBAL PROPAGATION salvages the possibility of me managing to time travel back to 1930 for at least *some* period of hypertime (namely all of the hypertimes between T_1 and $T_{\omega'}$).

Thus, we have at least one reason to take note of worlds at which GLOBAL PROPAGATION is true: At such worlds, multiple time travellers can go back in time to different destinations.

5.2. The Metaphysical Possibility of Time Travel Fictions

Recognising the possibility of propagative worlds also helps with determining which time travel stories are/are not metaphysically possible. This was Lewis’s task in his famous contribution to the philosophy of time travel [15]. He demonstrates that various time travel stories are possible (such as stories by Heinlein). Lewis was clear, though, that not any old time travel story was thereby possible and it remains interesting to ask of other stories whether they are possible or not. (Elsewhere [2], I have already discussed the possibility of other fictions, not covered by Lewis’s theory, nevertheless being possible—this paper furthers that investigation).

GLOBAL PROPAGATION allows us to capture the metaphysical possibility of it ‘taking time’ for changes to the past to ‘reach’ the present. This trope appears in a variety of stories, such as Baxter’s *Timelike Infinity* [41], Mark Millar’s *Chrononauts* [42], Robert J. Sawyer’s ‘On the Surface’ [43], *Star Trek: Enterprise’s* ‘Carpenter Street’ [44], and *Red Dwarf’s* ‘Timeslides’ [45], to name just a few. However, as this section explains, it turns out that only some such fictions turn out to be possible given GLOBAL PROPAGATION.

Consider a narrative that GLOBAL PROPAGATION does *not* bear out the possibility of: *Red Dwarf’s* ‘Timeslides’ [45]. Because of misadventure, the protagonist, Lister, is the last man alive in 3,000,000 AD. Finding a time machine, he returns to when he was a young adult (say, 2174 AD), changing history so he avoids his fate. He then returns to the future. At first, nothing changes. Asking why the past has not altered, Lister is informed that ‘it’ll take a few seconds for the timelines to sort themselves out’. Sure enough, a few seconds later the changes to history catch up to the present and Lister ceases to be; history is now different, with him having now lived a successful life in the past.

Whilst ‘Timeslides’ involves changes to the past taking a while to reach the present, its narrative is nevertheless *not* possible at a propagative world of exterminous hypertime. See Figure 4. At the earliest hypertime, T_1 , the past is such that Lister lives an unsuccessful life and goes back in time to change this. At T_ω , the past up until 2175 AD has changed. At $T_{\omega'}$, still more of the past has altered; Lister is now rich and famous in 2180 AD, rather than poor and unknown. At $T_{\omega''}$, even more of the past has changed and history is different up until 3000 AD. And so on, until we get to a hypertime, $T_{\omega'''}$, at which all of history reflects the changes Lister made. However, consider what happens at each hypertime. At $T_{\omega'}$, Lister returns to the future and . . . keeps on living. He does not vanish or fade away. Similarly for $T_{\omega''}$ and all other hypertimes hyperprior to $T_{\omega'''}$. Additionally, at $T_{\omega'''}$ there

is no Lister going back in the past in the first place because he lived a successful life and never got trapped in deep space. So there is *no* hypertime at which Lister stands around waiting to be washed away by the changes he made to the past, only to have those changes ‘catch up with him’. ‘Timeslides’ is *not* the sort of narrative which GLOBAL PROPAGATION bears out¹¹.

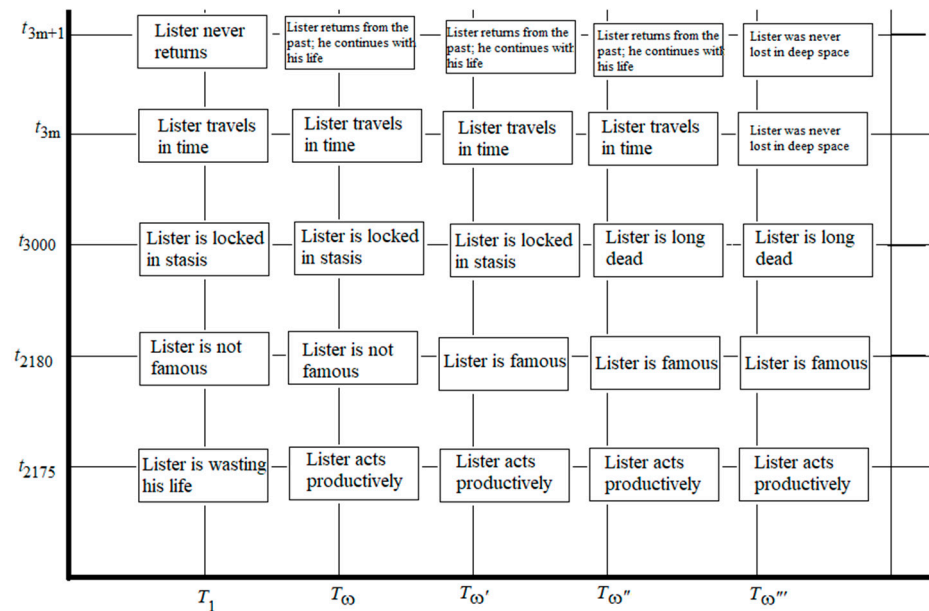


Figure 4. The narrative of Red Dwarf’s ‘Timeslides’.

However, that does not mean that propagative worlds cannot capture *any* narrative that involves changes to history taking time to ripple forwards. Given a suitably liberal interpretation, some such fictions are possible given GLOBAL PROPAGATION. Consider two examples.

The first example is Baxter’s *Timelike Infinity* [41]. Rebels have headed into the past to change history. One character, Jasoft Parz, wonders how their changes will affect him. He worries that there are no ‘estimates of the rate—in subjective terms—at which the disruption was approaching, emerging from the past as if from the depths of some dismal sea’ [41] (pp. 182–83). Whilst we might interpret Parz’s worry as reflecting the idea that changes to history are propagating through regular time, there is a legitimate interpretation whereby his worry is well-founded because the disruption is approaching hypertemporally. At the current hypertime, Parz will be unaffected. But Parz knows—and is concerned about—what hyperwill happen to him, and whether the changes to the past will affect him at some hyperlater hypertime (Such an interpretation requires it to be rational for Parz to worry about what will happen to him at hyperlater hypertimes; I pick this issue up in Section 6).

The second example is Millar and Murphy’s *Chrononauts* [42]. The characters worry that changes in the past are coming towards them, threatening to radically alter how things are. One character asks ‘How long have we got?’, asking how much longer they have, in the present, before the changes wipe them out.

It is natural to read this as a worry about changes to the past propagating through regular time. However, again, there is a legitimate interpretation whereby the changes are propagating through hypertime instead. Given that interpretation, we read the question ‘How long have we got?’ as concerning what period of *hypertime* it takes for the changes to reach the present. Given that interpretation, the comic still makes sense. And—assuming it is rational to worry about disasters in one’s hyperfuture—there is little reason *not* to interpret the strip that way.

6. Hyperexpectations

Section 5.2 argued that certain fictions are possible given GLOBAL PROPAGATION and assumed that it is rational to worry about what happens to you in the hyperfuture. This section argues for that assumption by discussing connected issues concerning persistence, expectation, and rational decision making in a world with two temporal dimensions.

6.1. Personal Hyperfutures

Set aside the question of Jasoft Parz and the Chrononauts for the time being. Consider instead the following case:

Case Five. Survival in a propagative world. Global Propagation is true. I am wondering whether to time travel from $t_{2021}-T_1$ to $t_{1930}-T_2$, i.e., I am wondering whether to time travel to 1930 AD. If I did, then the world would be as depicted in Figure 3. But—as Figure 3 makes clear—when I leave $t_{2021}-T_1$, I fail to appear at $t_{1930}-T_2$.

The worry is this: Since I fail to appear at $t_{1930}-T_2$, am I not effectively killing myself by travelling in time?

I believe this worry to be misplaced. To see why, consider a world with just a single dimension of time where I travel back in time from 2021 to the 1930s, intending to retire and never to return. We might worry that this effectively kills me, since—at 2021—I stop existing in the future. However, there is a well-rehearsed objection to this, relying on the distinction between me having an ‘external future’ and a ‘personal future’—if you are unfamiliar with the distinction between external time and personal time, see [15] and [1] (pp. 42–45). In that I do not exist at 2022, 2023, 2024, etc., I do not have an external future. However, I still have a personal future lying in the 1930s. It is my having a personal future that is important to rational decision making, hence why my time travelling retirement plan is rational.

Whilst it is true that, in Case Five, when I activate my time machine at $t_{2021}-T_1$ I have neither an external future nor a personal future, this line of thinking nevertheless helps. Given exterminous hypertime introduces two dimensions of external time, we should do the same for personal time: I have two types of personal history, my regular personal history and my personal hyperhistory. Just as my future stages are those stages which I immanently causally influence, my hyperfuture stages are those that I immanently causally influence by how I am now and by what I hyperpresently do. So in Case Five, there is a stage of me in the hyperfuture (e.g., at $t_{1930}-T_3, t_{1930}-T_3, t_{1930}-T_4 \dots t_{1930}-T_\omega \dots$) that I have immanently causally influenced, thus it is one of my personal hyperfuture stages¹². So whilst it is true that I may have no more personal future, I nevertheless have a personal hyperfuture. And it is in that personal hyperfuture that I end up having a personal future where I activate the time machine and go on to survive in the 1930s.

An event lying in one’s personal hyperfuture can be action guiding; my still having a post-time-machine-activation personal future at some hyperfuture time means that it is rational to travel back in time in Case Five. This is because it is rational to care about one’s personal hyperfuture in the same way that one cares about one’s personal future—your personal hyperfuture stages are stages of *you*, after all. Since they are stages you can still causally influence—in this case, hypercausally influence—it is natural to worry about what they hyperwill be like. Compare: In a world of one-dimensional time, it is rational for me to presently make sacrifices in order to benefit my future self. It is, for instance, rational to refrain from enjoying my delicious piña colada in order to flee a nearby erupting volcano, thus ensuring that my future self can drink many more cocktails later on. In a world of exterminous hypertime, the analogue applies and I should be motivated to make sacrifices to benefit my hyperfuture self, ensuring that my hyperfuture self has a personal history that lies in the (regular) past. Thus, if you want to travel back to the 1930s, it is rational to get into use the time machine in Case Five.

Indeed, we might be *more* motivated to worry about our hyperfutures than our regular futures. My biology is such that I am likely to live in the region of eighty or so years. However, given how hypercausation functions, I could potentially persist in the

hypertemporal direction for hypereternity. That said, time travellers might end up in a situation where they have to make hard choices. Imagine it is T_1 and a supervillain plans to go back in time and destroy all life on the planet from 50,000 BC onwards. If that happens at T_2 , you will have existed only hypermomentarily. But imagine the supervillain makes you an offer: In return for not foiling his scheme, the villain promises you an elixir giving you an extended life span, with excellent health throughout, for four hundred years. What do you do? Which is better? A longer ‘temporally regular’ existence but at only one hypertime? Or a shorter ‘regular’ existence but at a potentially infinite number of hypertimes?

6.2. Hyperexpectations

Having bifurcated personal time, we should similarly bifurcate the notion of *expectation*. Consider the following case.

Case Six. The Retrorifle Case. I live in a world where GLOBAL EFFECT is true. Rather than time travelling to 1930 in order to kill Hitler I instead fire a bullet from my ‘retrorifle’. Such a gun fires a bullet back in time from $t_{2021}-T_1$ to $t_{1930}-T_2$, shooting Hitler dead. However, I myself do not travel in time; I remain at T_1 .

In Case Six, what should I expect to happen when I fire the gun? At first glance, I should expect nothing to happen when I pull the trigger of the gun since my personal future lies wholly within T_1 and my retrorifle only causes history to be different at hyperlater hypertimes. So, we might think that I should not expect my firing the rifle to change the world around me.

There is something both substantially right about this, but also substantially wrong. Whilst my personal future will not reflect Hitler having being assassinated and World War II not happening, in my personal hyperfuture the world’s history is such that Hitler is dead. Having bifurcated personal time, we should do the same for expectation: Whilst I should not *expect* anything to change when I pull the retrorifle’s trigger, I should nevertheless *hyperexpect* things to change. My expectations track what will happen to me in my personal future; my hyperexpectations track what hyperwill happen to me in my personal hyperfuture. We can then reparse the claim that what happens to me in my hyperfuture is relevant to what decisions I make: What decisions I make should be based, not just on what I expect to happen given my actions, but also (at least partially) on what I hyperexpect to happen given my actions.

All that said, return to Jasoft Parz and the rationality of his worries. Given what I have said about expectations and hyperexpectations, Parz’s worries are rational because he is correct to hyperexpect that he, and the world around him, will be different in the hyperfuture. Indeed, given the changes made to the past, he might not even exist at all once the changes hyperreach him—his chance at existing for the rest of hypereternity is in jeopardy! So, as the fiction depicts, Parz’s worries are reasonable. Similar thinking applies to *Chrononauts*. As the characters stand chatting, they should not expect any changes to the past to hyperpresently affect them. However, they are nevertheless correct to worry—and take action in light of those worries—because of what they hyperexpect to happen.

So, GLOBAL PROPAGATION can help make sense of the metaphysical possibility of certain fictional narratives which we might previously have thought to be impossible.

7. Conclusions

It is interesting to see how exterminous hypertime can (i) avoid problems facing certain other models of time travel and (ii) expand the range of time travel fictions that turn out to be metaphysically possible. I stress again, though, that this is where one’s interest should likely stop, for there is no reason to think *our world* is a world of exterminous hypertime. Having said that, were you to ever find yourself in 1930 with a dead Hitler at your feet, then exterminous hypertime should be on your list of candidates as to which metaphysical theory might account for what you have just witnessed.

8. Appendix: The Metaphysics of Time

A referee asked about exterminous hypertime's commitments to the different theories in the metaphysics of time, e.g., must exterminous hypertime be tensed or tenseless, eternalist or presentist, etc.? This appendix deals with those issues, arguing that exterminous hypertime is compatible with any metaphysical theory of time except those committed to an open future.

8.1. Tenseless vs. Tensed Exterminous Hypertime

Consider a tenseless eternalist exterminous hypertime. Given the world is tenseless and eternalist, no time is metaphysically privileged, nor is any hypertime, nor is any time-hypertime¹³. All time-hypertimes exist *simpliciter*, whether they are later, earlier, hyperlater, or hyperearlier. I see no reason to think anything about this tenseless theory is problematic. If anything, it is the most natural understanding of exterminous hypertime.

It gets more interesting when we consider the tensed views. In regular worlds of one-dimensional time, tensed theorists say some time is metaphysically privileged. When we extend that to worlds of exterminous hypertime, it is most natural to think instead that some singular time-hypertime is metaphysically privileged¹⁴.

The rest of this appendix discusses what else we can say about the relationship between exterminous hypertime and the tensed theories of time.

8.2. The Dimensionality of the A-Series

Tensed theorists think that 'privilege forms a series'—namely, the 'A-series'. For instance, at a world of one-dimensional discrete time, consisting of times $t_1, t_2, t_3 \dots$, then first t_1 would be metaphysically privileged, then t_2 , then t_3 , etc. Represent that A-series as:

$$t_1 \Rightarrow t_2 \Rightarrow t_3 \Rightarrow \dots$$

Like the temporal dimension at that world, that A-series is one-dimensional. Tensed exterminous hypertemporal theorists would have a problem if, at worlds of exterminous hypertime, the A-series also had to be one-dimensional. At such worlds, there would be two options as to how such an A-series could be arranged, with each turning out to be a bad option.

Option (i): The series is ordered thus:

$$t_1-T_1 \Rightarrow t_2-T_1 \Rightarrow t_3-T_1 \Rightarrow \dots \Rightarrow t_1-T_2 \Rightarrow t_2-T_2 \Rightarrow t_3-T_2 \Rightarrow \dots \Rightarrow t_1-T_3 \Rightarrow t_2-T_3 \Rightarrow \dots$$

This option means that the spotlight of metaphysical privilege must work through every time at the first hypertime before it can move onto the second hypertime and start working through the eternity of times at that hypertime, and so on for all hypertimes. This is problematic because such a series is too similar to the series arising at a world of *one-dimensional time* where, after an eternity has passed, the universe 'resets' to how it was at the start and history starts cycling through again. Imagine that, at such a world, ostensible time travellers who step into their time machines in an earlier circle appear in 'the past' in the next cycle—in a sense, they have not travelled back in time, but have instead travelled an eternity into the future to a point where history has repeated itself. As far as I know, no-one has presented such a theory of time travel, but this short description should suffice in explaining it¹⁵. Given that theory, the A-series of events would be exactly like that given by option (i). So if the tensed exterminous hypertemporal theorist accepted option (i), I would worry that they were not really distinguishing their theory from this theory of time travel relying only on one-dimensional time.

There is also an apeirophobic problem with the A-series of option (i). Given option (i), metaphysical privilege only moves onto the next hypertime after an eternity has passed. There are Zeno-esque concerns that you will never reach the relevant point where privilege moves to the next hypertime—similarly, it is less clear that you should expect something

to happen if its happening is literally an infinite amount of time away. If that were true then we should never expect metaphysical privilege to move to the next hypertime and so should no longer ‘hyperexpect’ things that happen in our hyperfuture to come about.

All this said, I assume exterminous hypertemporal theorists will avoid option (i).

Option (ii): The time-hypertimes form the following series, whereby both time and hypertime are always ‘flowing forwards’:

$$t_1-T_1 \Rightarrow t_2-T_2 \Rightarrow t_3-T_3 \Rightarrow \dots$$

Given option (ii), some time-hypertimes (e.g., t_1-T_1 or t_2-T_2) are *never* privileged, which seems bizarre. Imagine the standard tensed theorist believed that there were events that are past but which somehow have avoided ever having the light of presentness shine down upon them. That would be crazy! Similarly, it would be weird if, at $t_{2021}-T_{2021}$, it was true that Hitler was alive in 1930 in virtue of how $t_{1930}-T_{2021}$ is, even though $t_{1930}-T_{2021}$ failed to appear in the A-series and failed to have ever been metaphysically privileged.

So, it is problematic to combine a one-dimensional A-series with two temporal dimensions. However, this is not a problem, since the exterminous hypertemporal theorist should simply say that the A-series is two-dimensional! Given a two-dimensional A-series it makes no sense to think that there is a single time-hypertime that comes ‘next’ in the A-series. Rather, there is a time-hypertime that comes next in one dimension of the A-series and a different time-hypertime that comes next in the other dimension. For example, if t_1-T_1 is metaphysically privileged then it makes no sense to ask which time-hypertime comes next *simpliciter*. Rather, we should say that t_2-T_1 comes next in one dimension of the A-series whilst t_1-T_2 comes next in another dimension of it. Once we accept that it can be two-dimensional, this problem about ordering the A-series goes away.

Some tensed theorists may struggle with the idea of a two-dimensional A-series. They might, for instance, be wedded to the metaphor of God being sat outside spacetime, in his own (one-dimensional) temporal stream, watching different parts of spacetime ‘light up’ as the spotlight of metaphysical privilege shines upon it. Such a metaphor leaves no room for a two-dimensional A-series. However, such tensed theorists are surely going to think two-dimensional *time* is also impossible—to think that time can be two-dimensional, but that the A-series must be one-dimensional, seems particularly strange. So, since this paper has already assumed that two-dimensional time is possible, I will assume that a two-dimensional A-series is equally unproblematic.

8.3. Presentist/Moving Spotlight Exterminous Hypertime

Armed with a two-dimensional A-series, exterminous hypertime can be married with different tensed ontologies. Consider a presentist theory whereby only one time-hypertime exists. The non-present non-hyperpresent time-hypertimes do not exist; however—just as other times did and will exist given regular presentism—those time-hypertimes did exist, will exist, hyperdid exist, and/or hyperwill exist. (Additionally, on this view, it makes no sense to ask which time-hypertime will be next *simpliciter* in the A-series, only whether a time-hypertime will be next in in one-dimension of the A-series or the other).

Similar can be said of the moving spotlight theory. Only one time-hypertime is metaphysically privileged. When you are at a metaphysically privileged time-hypertime, the spotlight will next move to different time-hypertimes depending upon whether we consider the dimension of the A-series corresponding to regular time or the dimension corresponding to hypertime—pick a different dimension, and a different time-hypertime will be ‘next’.

8.4. Growing Block Theory and the Open Future

Things become more complicated when we consider growing block theory. Firstly, we must pin down the details of what growing block theory amounts to in a world with two temporal dimensions. It is natural for such growing block theorists to say that nothing hyperlater than the metaphysically privileged time-hypertime exists. Equally, it is natural

to say that any earlier-and-hyperearlier, as well as any earlier-and-hypersimultaneous, time-hypertimes exist. However, this does not settle the status of all time-hypertimes. Growing block theorists have two options when it comes to hyperearlier-yet-later time-hypertimes: Either they exist or they do not. Figure 5a depicts a growing block whereby such time-hypertimes *do* exist; call it 'Bigger growing block theory'. Figure 5b depicts a growing block theory whereby those time-hypertimes do not exist; call it 'Littler growing block theory' (because its block is smaller than that of Bigger growing block theory). Both have problems when it comes to their compatibility with exterminous hypertime.

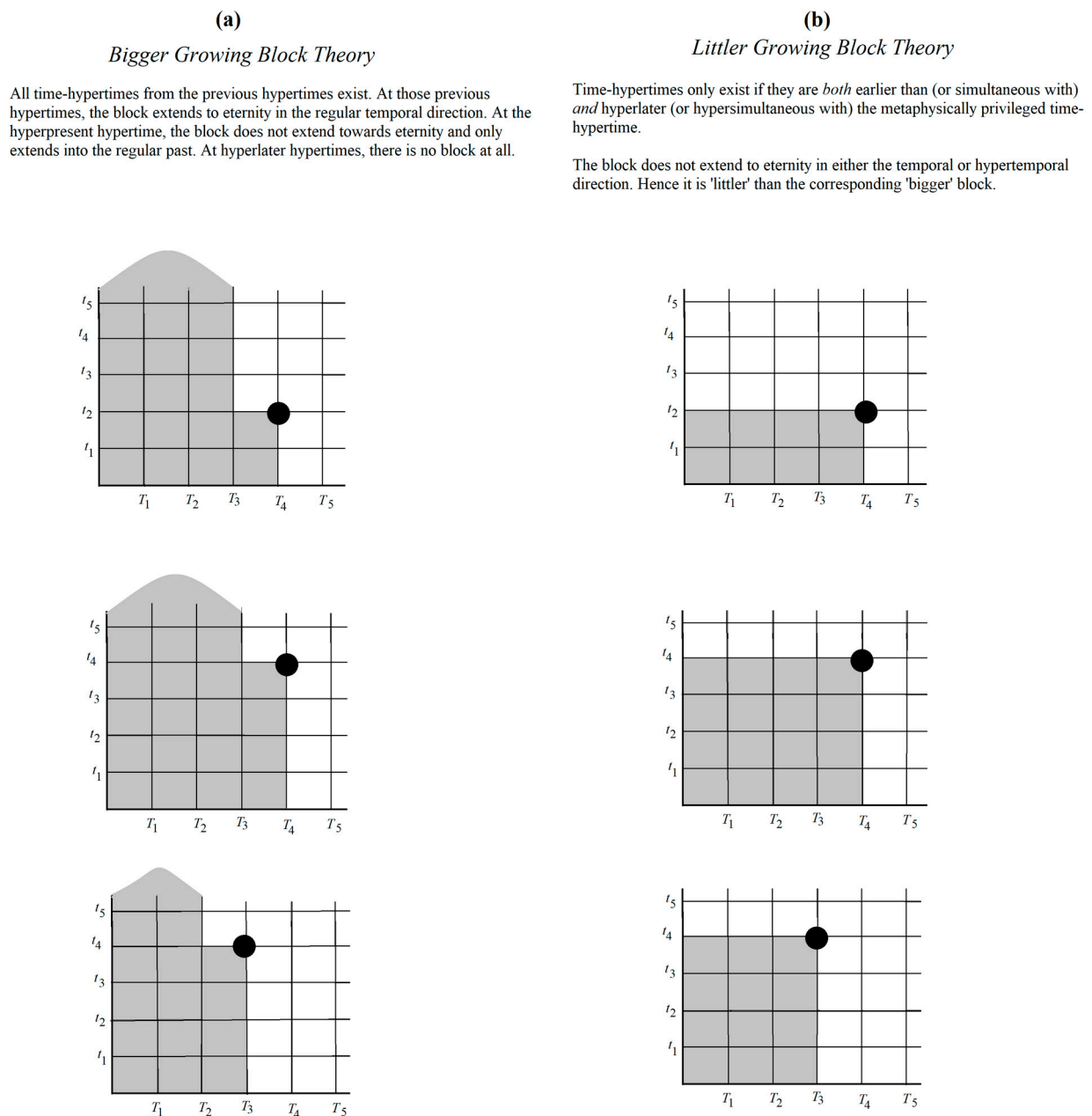


Figure 5. Growing Block Theory & Exterminous Hypertime, (a) Bigger Growing Block Theory, (b) Littler Growing Block Theory. In each of the diagrams, the black dot indicates which time-hypertime is metaphysically privileged. The greys shading indicates the size of the growing block; every time-hypertime covered by the grey shading exists.

Consider Bigger growing block theory. If all time-hypertimes that are hyperprevious-yet-later exist, then we once again end up with a one-dimensional A-series. To see why,

consider the standard growing block theorist who believes in just one dimension of time. They define the relation of precedence in the A-series as:

For all j and k : t_j precedes t_k iff the times that exist when t_j is privileged are a subset of the times that exist when t_k is privileged.

Bigger growing block theory can (and, presumably, should!) accept the analogue:

For all j, k, m , and n : t_m-T_n precedes t_j-T_k iff the time-hypertimes that exist when t_m-T_n is privileged are a subset of the time-hypertimes that exist when t_j-T_k is privileged.

Given that analogue principle, there would then be a one-dimensional A-series like the following:

$$t_1-T_1 \Rightarrow t_2-T_1 \Rightarrow t_3-T_1 \Rightarrow \dots \Rightarrow t_1-T_2 \Rightarrow t_2-T_2 \Rightarrow t_3-T_2 \Rightarrow \dots \Rightarrow t_1-T_3 \Rightarrow t_2-T_3 \Rightarrow \dots$$

However, that is just the ordering from option (i) above! Since that ordering was problematic, so too is Bigger growing block theory.

Littler growing block theory also has problems, although this time they stem from the incompatibility of exterminous hypertimes with an open future. Open future theorists believe that facts about later times are indeterminate. Given exterminous hypertime involves two dimensions of time, open future theory must be redescribed. Clearly, that redescription should say that what is hypersimultaneous-and-later is indeterminate, as is anything hyperlater-and-later (and, presumably, anything *at all* that is hyperlater). However, there are two options concerning the status of facts about hyperearlier-and-later time-hypertimes:

- (a) Facts about hyperearlier-and-later time-hypertimes are determinate; or
- (b) Facts about *any* later time-hypertime—whether that time-hypertime is hyperearlier, hypersimultaneous, or hyperlater—are indeterminate.

Option (a) leads to the same problem we had with Bigger growing block theory. Given (a), the facts become determinate in a certain order. All facts at one hypertime go from being indeterminate to being determinate (in order of earliest to latest) and only once facts about all time-hypertimes at any given hypertime are settled, do facts at the hypernext hypertime begin to get settled (again, in order of earliest to latest in the regular temporal series). So there would, again, be a one dimensional A-series of the form:

$$t_1-T_1 \Rightarrow t_2-T_1 \Rightarrow t_3-T_1 \Rightarrow \dots \Rightarrow t_1-T_2 \Rightarrow t_2-T_2 \Rightarrow t_3-T_2 \Rightarrow \dots \Rightarrow t_1-T_3 \Rightarrow t_2-T_3 \Rightarrow \dots$$

I have already argued that such a one-dimensional A-series is problematic. So option (a) is a bad option.

Option (b) has its own problem. Consider the following scenario. It is presently and hyperpresently $t_{1999}-T_{1999}$. Given option (b), facts about hyperearlier/hypersimultaneous earlier times are fixed, so facts about $t_{1930}-T_{1998}$ and $t_{1930}-T_{1999}$ are fixed. Let us say, for example, that it is hyperpresently true that Hitler exists at both those time-hypertimes and at neither does a time traveller turn up to kill him. Given option (b), it is further indeterminate whether, at $t_{2021}-T_{1998}$, a time traveller leaves that time-hypertime to go and kill Hitler in 1930. Next, imagine time passes and $t_{2021}-T_{2021}$ becomes hyperpresent/present. There would then also be determinate facts about $t_{2021}-T_{1998}$. Imagine that those facts end up being such that, at $t_{2021}-t_{1998}$, a time traveller *does* go back to 1930 to kill Hitler. Given PROGRESSION, that time traveller must arrive at $t_{1930}-T_{1999}$. However, we have assumed for purpose of example that no such time traveller exists at $t_{1930}-T_{1999}$. So we would now have a contradiction. So option (b) is problematic. Therefore, since option (a) is problematic as well, we cannot pair exterminous hypertime with an open future. (Is it a problem that exterminous hypertime is incompatible with an open future? I presume not. Very few theories of time travel can make room for the future being open [1] (p. 71 n. 3), so it is not concerning that exterminous hypertime ends up in the same boat).

That conclusion in place, return to Littler growing block theory. Stereotypically, growing block theorists are open future theorists—because the future times do not exist, facts about them are unsettled [46] (p. 27–28) [47] (p. 357) [48,49]. Once we add in exterminous hypertime, the natural extension of that stereotype is to say that if a time-hypertime does not exist then facts about it are unsettled. So, if they also indulge in that stereotype, Littler growing block theorists will endorse option (b), which I have argued leads to a contradiction. In short: Unless one is willing to ditch the growing block theorist's traditional commitment to an open future, growing block theory is incompatible with exterminous hypertime. (Similarly, any other tensed theory that allows for an open future will have the same problem—for instance, if you are a presentist or moving spotlight theorist who believes the future is open, then that tensed theory will also be incompatible with exterminous hypertime.)

8.5. Summary

Exterminous hypertime is compatible with the tenseless theory of time and—as long as you are willing to accept a two-dimensional A-series—certain tensed theories of time. The tensed theories that are incompatible are any that accept that the future is open.

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Notes

- 1 Even given time travel is physically impossible, some people might think the following question was of interest: 'If time travel were physically possible, then what model of time travel would be true?'. However, that the question is as odd as asking whether, were magic possible, would it work like it does in *Harry Potter* or as it does in *Dungeons and Dragons*? What a bizarre question that is! Similarly, unless time travel is physically possible, I doubt any sensible answer to that counterfactual question will be forthcoming.
- 2 Throughout this paper, I assume PROGRESSION is true. Elsewhere [2], I discuss exterminous hypertemporal worlds at which PROGRESSION is false and 'hypertime travel', where one can travel into the hyperpast, is possible.
- 3 This footnote discusses the topology of hypertime. A temporal series is discrete iff, with the exception of the first and last instants, every instant has an immediately prior instant and an immediately later instant. (Where x is immediately prior to y iff x is earlier than y and there is no z such that z is earlier than y and later than x ; a similar definition applies to 'immediately later'.) A temporal series is dense iff between any two instants there is a third instant [50] (p. 23) [51] (pp. 195–218) [52] (p. 112). Clearly, no dense series is discrete and no discrete series is dense. (Another way of thinking about it is to think of a discrete temporal series as being contiguous to the natural number series, e.g., $\dots -1, -2, 0, 1, 2 \dots$, whilst a dense series is contiguous to, e.g., the irrational number series or real number series.) Whilst it might be technically possible to believe in both PROGRESSION and dense hypertime, the most natural interpretation is that time travellers leave one hypertime and move to the 'next' hypertime. Since believing that there is a 'next' hypertime is just to believe that hypertime is discrete, throughout this paper, I assume that hypertime is discrete.
- 4 Smith intends this to be a problem for Goddu's theory of hypertime [3] (and Meiland's [53], but I have elsewhere suggested that Meiland's theory is not a hypertemporal theory at all [40]). Goddu does not believe hypertime is exterminous, instead believing it to be 'conterminous' (see also [1] (p. 76–77)). Conterminous hypertime is different from exterminous hypertime in that, at any given hypertime, only one regular time exists. Further, as time advances, hypertime advances. Two examples help clarify the difference. Where \blacktriangleleft is the 'hyperearlier than' relation:

Example One: In a time travel case where I kill Hitler, conterminous theorists order the time-hypertimes thus:

$$t_{1930}-T_{1930} \blacktriangleleft t_{1939}-T_{1939} \blacktriangleleft t_{2021}-T_{2021} \blacktriangleleft t_{1930}-T_{2022} \blacktriangleleft t_{1939}-T_{2031} \blacktriangleleft \dots$$

Example Two: In a non-time travel case, e.g., the liberation of Haiti, the regular temporal series is always 'in step' with the hypertemporal series, e.g.,:

$$t_{1803}-T_{1803} \blacktriangleleft t_{1804}-T_{1804} \blacktriangleleft t_{1805}-T_{1805} \blacktriangleleft \dots t_{2021}-T_{2021} \blacktriangleleft \dots$$

Given such orderings, Smith's overdetermination worry is not a problem, although for reasons different than for the exterminous theorist. Consider the Haiti example. Exterminous hypertime has a problem because the events at one time-hypertime (i.e., $t_{1804}-T_2$) are overdetermined in virtue of being caused by events from two distinct time-hypertimes (e.g.,

from the earlier $t_{1803}-T_2$ as well as the hyperearlier $t_{1804}-T_1$). No such problem arises given conterminous hypertime. Whilst the conterminous hypertemporal theorist believes that the liberation at $t_{1804}-T_{1804}$ is caused by earlier events *and* caused by hyperearlier events, they are not *distinct* events—the causes earlier in regular time and the causes that are hyperearlier are numerically identical events! Since the events are not distinct, there is not an overdetermination challenge to begin with.

5 For discussion of the problem of systematic overdetermination being one of unlikelihood, see Funkhouser [54] (pp. 333–338). Other philosophers believe that the problem is something other than unlikelihood (see [55] for discussion); this paper ignores those alternative understandings of the problem of overdetermination.

6 Smith explicitly likens the problem of overdetermination in the hypertemporal case to the problem of overdetermination in the philosophy of mind (and, when I wrote about the problem [1] (pp. 83–84), I had a similar issue in mind). It is worth noting, then, that when it comes to the problem of overdetermination in the philosophy of mind there are already philosophers who argue against the problem for very similar reasons that I have just given [56,57] (pp. 227–228) [58] (p. 452) [59] (see also [60] and [61] (pp. 722–723)).

7 A referee raised a worry. Physics says that the half-life of moscovium-287 is 37 milliseconds, i.e., its probability of decaying during that period is 0.5. When I say that its ‘objective chance’ of decaying in that period is instead 1 and its ‘chance_{chc}’ of decaying is 0.5, you might think I have become *definitionally confused*. ‘Objective chance’ picks out just that probability function which physicists are interested in, i.e., the function that says moscovium’s probability of decay is 0.5. So what I call ‘chance_{chc}’ just is what we call ‘objective chance’; moreover, what I call ‘objective chance’ must be a totally different function—a function that we might worry is so weird and bizarre that it cannot play a serious philosophical role. The worry is misplaced. Compare to a case where we consider some quantum event which we usually believe has a chance of occurring between 0 and 1. However, imagine it turned out that the ‘hidden variable theory’ was true, whereby quantum events occur (or not) because of purely deterministic features of the world that we do not have access to. A superscientist who had access to those variables—and who could carry out the appropriate predictions—would see of every event that its chance was either 0 or 1; this would be true, even though more ignorant scientists *justifiably* treated those events as being genuinely stochastic. I claim that there is at least one context/interpretation/understanding whereby: (i) the superscientist is correct to say that the probability function given by the hidden variables is the ‘objective chance’ function; whilst (ii) the probability function which ignorant scientists are interested in is instrumentally useful, even if it is *not* the objective chance function. If you hold fixed that context/interpretation/understanding, the initial worry of this footnote goes away. A physicist in Case One who was availed of the true laws of nature will, if they suspect they are at a hyperinstant later than T_1 , know that all later events have an objective chance of occurring equal to either 0 or 1. However, since there is no time travel in Case One, that physicist will be ignorant of what those chances are. So she—along with her more ignorant colleagues who do not know that later events are nominally enslaved to hyperearlier events—will routinely talk about the moscovium atom having a probability of decaying other than 0 or 1. She correctly recognises that the probability function she is aiming for when she talks in this fashion (i.e., the ‘chance_{chc} function’) is not the objective chance function, but it is nevertheless still a perspicuous function that she, and all other scientists, can and should make use of. So I do not think there is any definitional confusion in what I say in the main text. (Additionally, note that there *are* time-hypertimes at which the decay of the moscovium atom is a chancey affair. At $t_{2021}-T_1$ the objective chance of the atom decaying a few milliseconds later at T_1 is 0.5. That also means that it is *also* true at $t_{2021}-T_1$ that the atom’s objective chance of decaying at $t_{2021}-T_2$ is 0.5. It is only later on that its chance increases to 1.)

8 In regular one-dimensional temporal worlds, the chance of an event occurring at an *earlier* time is always 0 or 1, for once the event has/has not happened, it is no longer a matter of chance as to whether it did/did not happen. A similar principle must be true of exterminous hypertemporal worlds—this paper assumes that the chance of events at any hyperearlier time-hypertime is equal to 0 or 1. That is: Even events that occur in your (regular) future are no longer chancey as long as they occurred in the hyperearlier hyperpast.

9 Footnote 3 argued that hypertime is discrete. Given Global Propagation, regular time must also be discrete because changes to history ripple forward at the rate of one temporal instant per hypertemporal instant, thus one series cannot be continuous whilst the other is discrete. (Discussions of discrete time include [52,62–64] (pp. 114–121); note that, for my purposes, time need only be *possibly* discrete, not *actually* discrete.) One option is that regular time is composed of finitely many ‘temporal atoms’. (Such temporal atomicity has been maintained by the likes of: Martinus Capella, the Buddhist Santarankitas, Abu’l-Hasan al Ash’ari, and Abu’l-Mansur al-Maturidi of Samarqand [65]; al-Ghazali and the Mutakallimun, the Greek Epicureans, the medieval philosophers Joannes Canonicus and Nicholas Bonet, and the Jewish philosopher Moses Maimonides [66] (pp. 34–35); (arguably) Descartes [67] (p. 627 n. 2); and the early Russell [68] (p. 6)). Changes to history would then take a finite number of hyperinstants to ripple forwards. For instance, if I time travel to 1930 and kill Hitler then we need only wait until, say, $t_{2021}-T_{\text{googol}}$ for 2021 to be such that World War II never occurred. A second option is that time is composed of an infinite, yet discrete, number of instants. In that case, I would have to wait until, say, $t_{1930}-T_{\omega}$ for 2021 to be such that World War II never occurred. (Thanks to Emily Thomas for help with the history of belief in temporal atomicity.)

10 I trialled a similar solution elsewhere [40], but at the time I did not think it worked (for reasons spelled out in that paper). In that paper, I was considering ‘past vacillation theory’, which is quite different from exterminous hypertime. Nevertheless, the theory of hyper-resilience spelled out in Section 4.2 could probably be tweaked to work for the theory of past vacillation and allow that theory to similarly avoid the Multiple Time Travellers problem.

- 11 Following on from *fn10*, I suspect that if changes propagated through vacillating time, rather than exterminous hypertime, we probably *could* allow for the possibility of the narrative of ‘Timeslides’ (at least, that element of it—there are other elements of the narrative, not discussed in this paper, that might prove problematic).
- 12 This raises the question of what it takes for a stage from some future hypertime to be a stage of Nikk Effingham rather than someone else. I have argued elsewhere that there are no great pitfalls to be faced on this issue [1] (see also [5] (pp. 3–4) and [10] (pp. 92–107) for discussion), so I am happy to assume that the hyperfuture stages I pick out are, indeed, stages of Nikk Effingham.
- 13 We can rigorously define what a time and a hypertime is:
 t is a time =_{df} t is a fusion of the x s whereby: (i) each x is a time-hypertime; (ii) each x is simultaneous with every other x ; and (iii) nothing simultaneous with an x fails to be amongst the x s.
 T is a hypertime =_{df} T is a fusion of the y s whereby: (i) each y is a time-hypertime; (ii) each y is hypersimultaneous with every other y ; and (iii) nothing hypersimultaneous with a y fails to be amongst the y s.
- 14 Instead of a time-hypertime being privileged, we might think that a hypertime is privileged (and that *all* time-hypertimes at that hypertime are likewise privileged). A weirder alternative is that the present *time* is metaphysically privileged. I do not discuss these alternatives because they seem substantially less plausible than the view discussed in the main text.
- 15 This form of time travel does appear in fiction, e.g., in *Futurama*’s ‘The Late Philip J. Fry’ [69]. Additionally, whilst I do not know of any metaphysician who proposes such a theory, there is a similar theory in the same ballpark [70] (see also [1] (p. 23)).

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