The Metaphysics of the Thin Red Line

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Abstract The thin red line is the view that time branches towards the future, but future contingent has already in the present a determinate truth-value. On the face of it, such a view avoids determinism and fatalism, while also representing the fact that there is a future which is 'special' because it is the one that will be the case. However, many have objected to the tenability of the thin red line theory by arguing that either it collapses on linear time or it compels us to endorse thick metaphysical theses about the future. In this chapter, we argue against such attacks and show that TRL's metaphysical grounds are solid.

Keywords Branching time theory • Thin red line • Metaphysics of the thin red line

There seems to be a minimal core that every theory wishing to accommodate the intuition that the future is open must contain: a denial of *physical determinism* (i.e. the thesis that what future states the universe will be in is implied by what states it has been in) and a denial of *strong fatalism* (i.e. the thesis that, at every time, what will subsequently be the case is metaphysically necessary).[1] Those two requirements

[1] Hence, strong fatalism implies physical determinism, while the latter does not imply the former, thus being compatible with the world having been otherwise, assuming that the initial condition of the world could have been otherwise. Also, strong fatalism is intended as opposed to weak fatalism, according to which whatever I will do now will not affect what will be the case. Weak fatalism, instead, does not imply, nor is implied, by physical determinism.

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are often associated with the idea of an objective temporal flow and the non-reality of the future. However, at least certain ways to frame the 'openness' intuition do not rely on any of these. Branching time theory (BTT) is one such: it is compatible with the denial that time flow is objective and it is couched in a language with a (*prima facie*) commitment to an eternalist ontology. BTT, though, urges us to resist certain intuitions about the determinacy of future claims, which arguably do not lead either to physical determinism or to fatalism. Against BTT, supporters of the thin red line theory (TRL) argue that their position avoids determinism and fatalism, while also representing the fact that there is a future which is 'special' because it is the one that will be the case. But starting with Belnap and Green (1994), some have objected to the tenability of TRL, mainly on metaphysical grounds. In particular, they argue that 'positing a thin red line amounts to giving up objective indeterminism'[2] and that 'has unacceptable consequences, ranging from a mistreatment of actuality to an inability to talk coherently about what *would* have happened had what is *going* to happen not taken place'.[3] In this chapter, we wish to reframe the dispute, thus showing that TRL's metaphysical grounds are solid and that it does not imply strong fatalism or determinism.

Branching Time and Alternative Futures

BTT allows us to clearly distinguish between deterministic and indeterministic views of reality, but it does not force us to choose between the two. As its proponents make clear,[4] BTT is a theory about the topology of time in our world, that is, it tells us how moments of time are connected to each other with respect to their temporal order. Using a metaphor, BTT states that the temporal order of our world has the shape of a tree. With respect to each moment, there is a unique *trunk* of past moments and a multiplicity of future *branches*. More precisely, a tree-world is a structure $T^b = <E, <>$ such that E is a set of moments, $<$ is a partial order relation defined on couples of elements of E (i.e. $<$ is transitive and antisymmetric, and $<=$ is reflexive). The trunk is a chain of moments in linear order whose upper bound is a certain moment t (which intuitively we can think of as the present moment), while the branches are chains of moments, such that any chain stands in no temporal relation to any other chain, but all are future with respect to t. A postulate of *no-backward branching* warrants that branches of temporally incomparable moments are all and only to be found in the future of each given moment.[5] Therefore, moments are temporally comparable only if they are on the trunk or they belong to the

[2] MacFarlane (2003): 325.

[3] Belnap and Green (1994): 367.

[4] Prior (1967), Thomason (1970, 1984), Belnap (1992), and Belnap et al. (2001)

[5] Belnap et al. (2001): 140. The other postulates are *non-triviality* (the structure is not empty), *partial order* and *historical connection* (for every distinct t_1 and $t2$ there is a t_3 such that $t_1 > t_3$ and $t_2 > t_3$). In order to keep the discussion under more familiar terms, our characterization of branching time theory differs in some minor respects from the one offered in Belnap et al. (2001) and Thomason (1970, 1984).

same branch. All tree structures compose a class, **Σ**. Such a class represents how, at each moment, there are many alternative futures, while the past is settled. A chain of moments is a series such that, for any two distinct moments t_x and t_y belonging to the series, either $t_x < t_y$ or $t_y < t_x$. Finally, a *history* can be defined as a maximal chain of moments.

Since BTT is about *our world's* temporal structure, it construes moments as concrete entities. Moments are indeed spatially complete instantaneous events (Belnap et al. 2001: 139), that is, instantaneous events that encompass the whole universe, from a spatial perspective.[6] A tree structure can thus also be defined on a domain of instantaneous events that may be 'smaller' than whole moments, with the relation '<' holding between instantaneous events (e.g. $e_x < e_y$) and thus also between moments (e.g. $t_x < t_y$). Events smaller than moments (from now on simply 'events') can be part of moments (and of other 'bigger' events in general). Although the branching time theory does not need to fully specify the mereological relations between events and moments, there are two interesting constraints on the part-whole relation between the two, which should hold in any formalization of it. Firstly, a moment *t* is a spatially complete instantaneous event whose parts are all and only events *simultaneous* with each other. Secondly, no event is part of two distinct moments. (Incidentally, from these constraints follow that $e_x < e_y$ if and only if there are two moments t_x and t_y, such that e_x is part of t_x, e_y is part of t_y and $t_x < t_y$, as we may expect.)

The constraints are interesting within a branching time structure because they force us to distinguish between the relations of genuine simultaneity and cross-simultaneity between events. *Genuine simultaneity* is a temporal relation between events. If we graph the ordering relation '<' on the natural or the real (depending whether we deem time to be discrete or not, respectively) in order to define a temporal metric between events, the simultaneity relation will be the zero-distance relation '$<_0$'.[7] It follows that such a relation holds only for same-branch events (as do temporal relations in general). *Cross-simultaneity* is instead defined in terms of same temporal distance from a moment.[8] A moment is cross-simultaneous with another moment if and only if they are at the same temporal distance from the present. Given that branching occurs only with respect to the future, cross-simultaneity only holds between *distinct* moments if these moments are future. (An alternative would have been to define the relation only for moments in the future.) The relation of cross-simultaneity allows us to define the notion of *instant* as a maximal set of cross-simultaneous moments. Because in the past and the present there is no branching, past moments and the present are instants; future moments, instead, are

[6] Of course, in a relativistic setting, the division of space-time into moments is always relative to a system of coordinates. We will not consider here the further complications due to special and general relativity (for a formulation of BTT in a relativistic space-time, see Belnap 1992).

[7] Alternatively, we can define simultaneity between events in terms of identity of moments: two events are simultaneous if and only if they belong to the same moment. Here, neither we are interested in providing a detailed formalization of our account nor we deem necessary to discuss what notions should be taken as primitive, since nothing of what we claim depends on these tasks.

[8] We are not forced to have a metric on '>' to define cross-simultaneity; we only need a relation of *same temporal distance* from a moment. Of course, within a temporal metric, such a relation is trivially defined.

only 'partial-instants' because they are elements of instants. If all histories are isomorphic, the class of *instants* is a linear order.[9]

Completing the sketch of the theory, let us define also the relations of *same-branchness*[10] and *same-worldliness* between events. Events e_x and e_y are same-branch if and only if $e_x < e_y$ or $e_y < e_x$, that is, two events are on the same branch if and only if there is a temporal relation between them. Events e_x and e_y are same-worldly if and only if there is an event e_z such that $e_z < e_x$ and $e_z < e_y$, that is, two events are in the same world only if there is another event with which they are both in a temporal relation.[11] Notice that, as we have defined them, same-wordliness is an equivalence relation, while same-branchness is not even Euclidean (e_t can be on the same branch both of e_x and e_y, while e_x not being on the same branch of e_y). Indeed, each event on the trunk of a tree is on the same branch of any other event on any other branch, but of course, events on different branches do not stand in the relation of same-branchness to each other.

The branching structure of temporal relations has been sometimes invoked to back up the idea that the passage of time is objective or that the future is unreal. McCall, for instance, explicitly grounds the mind-independence reality of the passage on the mind-independence of the direction of the temporal relation,[12] and Prior seems to suggest, furthermore, that the indeterminacy captured by the branching structure is due to the unreality of the future.[13] However, most often, BTT is invoked to back up

[9] Note that we are not postulating isomorphism between histories and *then* define instants on such grounds. Our definition of instant holds even if there is not a complete order of instants.

[10] The reader should be alerted that what we call *same-branchness* most often goes by *same-historiness*. An analogous remark applies for *determinate/indeterminate at a branch* and *necessary/possible at a branch*, which would usually be called *determinate/indeterminate with respect to a history* and *necessary/possible with respect to a history*. We prefer the term 'branch' as we find it theoretically more neutral. In particular, and as we shall clarify later, the totality of the branches of a tree may not (and in most cases do not) represent the totality of the metaphysical possibilities at a time. Yet we find that speaking of the totality of histories may, although only implicitly, suggest the misguided reading.

[11] The postulate of *historical connection* (for every distinct t_1 and t_2, there is a t_3 such that $t_3 < t_1$ and $t_3 < t_2$) in Belnap et al. (2001) makes each moment trivially same-wordly with any other. This is a difference between their formulation and ours. Indeed, as it will be clear below, we aim at characterizing the structure also with respect to metaphysically possible alternative situations and not just with respect to our world.

[12] McCall (1984). The idea that indeterminist causality can be exploited to ground the 'arrow' of time, that is, not simply a temporal asymmetry between the two directions of the temporal relation but also a preferred direction as *the* direction of time dates back to Reichenbach (1956); see also Horwich (1987).

[13] Prior (1967). In what follows, we will speak as if future moments are real, as usually branching theorists do. If topological connection requires sameness of ontological status and there is at least one real moment on a tree (for instance, the present), then this follows (see note 20). However, what is relevant here is that (i) branching time is *compatible* with the thesis that future moments are ontologically on a par with the present and the past and (ii) branching time vindicates the intuition of openness *not* through an ontological difference between the past and the future (even granting there is any). Besides, we will often speak in terms of the present, along with past and future moments. These locutions – 'present', 'past' and 'future' – have to be taken informally, since nothing of what we claim hinges on endorsing some dynamic or tense-realist view.

the idea that the future is genuinely – objectively and ontologically – undetermined, which is a logically independent thesis both from the hypothesis that the future is unreal and the hypothesis that the passage of time is objective. BTT nicely spells out the intuition that the future is indeterminate by positing a difference in the topological structure of the future with respect to the past and present. BTT does not spell out the indeterminacy intuition by appealing to an objective flow of the present, since the fundamental temporal relation that it resorts to can be construed as the standard 'static' relation of the B-theorist; neither it spells out such intuition by bestowing upon the future a different ontological status than the past and the present, as all future events are connected to the present moment (and the past) and thus are part of the same world. This is something which is important to keep in mind, because BTT friends cannot resort to those further metaphysical theses in defending their position and arguing against the TRL alternative.

Here is the trick: although any future event is connected to the present, there may be no temporal connection between future events in a world (including our world); thus, unconnected future events stand on *alternative* branches; they are alternative futures. More precisely, at a moment *t*, an event e_x (on any branch) is *an alternative future with respect to an event* e_y if and only if both e_x and e_y lie ahead of *t*, they are at the same temporal distance from *t* and e_x is on a different branch than e_y. And at a moment *t*, e_x is *among the alternative futures of t* if and only if $t < e_x$ and there is some e_y such that it is not the case that $e_x < e_y$ or $e_y < e_x$.

What we call 'alternative future' is also named 'possible future' or, as Belnap and Green put it, an event 'in the future possibilities of' a moment.[14] However, we believe that this qualification is misleading. Granted, the two events e_x and e_y are both in the same world; if we take such world to be the actual world, then e_x and e_y are both actual, and since whatever is actual is also possible, e_x and e_y are indeed possible. Still, calling e_x and e_y 'possible futures' may lead one to think that they exist in different worlds and, perhaps, in different ways from what is actual. Yet they are alternative just in virtue of the fact that they are temporally non-related, while both being future with respect to a same present. Hence, we prefer to say that events on different branches are alternative futures. Distinct cross-simultaneous events form a subset of the set of alternative futures. It is important to bear in mind that there is no ontological difference between alternative futures and present and past moments – or at least that no such difference is of any relevance for BTT. As we shall clarify later, on BTT it is indeterminate what your future *will* be, although it is not indeterminate what your alternatives *are*.

Thus, BTT is not a theory of (metaphysical) possibility and necessity. Indeed, there may be more metaphysical possibilities for a present event at a certain world than those represented by the branches of the tree of that world. In other words, we are here assuming that trees within BTT are generated through a principle of humean (or quasi-humean) recombination.[15] Thus, even if we find (no) event of a

[14] Belnap et al. (2001): 140 and Belnap and Green (1994): 371.

[15] See, for example, Lewis (1986): 89.

certain kind on every alternative future of a moment *t*, it will not be the case that an event of that kind is necessarily (not) going to happen; in other words, what *has to be* the case according to a certain tree-world may not be what *necessarily* has to be the case.

This suggests a natural way to expand the theory from a single world-tree to a class of such, representing the class of the metaphysically possible worlds. Instead of having a world-tree only $T^{\flat} = <E, <>$, we have a structure $S = <E, \boldsymbol{T}^{\flat}>$, where $\boldsymbol{T}^{\flat}$ is a set of world-tree and E is the union of all *E* in each $T^{\flat}$. S is the space of metaphysically possible worlds, some of which may have a branching structure and some of them may partially overlap (by sharing the same events in the same order up to a certain moment). As we have shaped it, thus, BTT offers a clear model accounting for the intuition that the future is open by providing a class of worlds such that, for any world in that class, the future may be open in a different way, namely, with respect to different alternatives.

Such a formal apparatus leaves us rather free to represent different kinds of determination and possibility. Although many options are available, we will follow this idea: each world-tree represents the *physically possible* continuation of the world's history at each of its moments; a world-tree structure represents the metaphysically possible alternatives for a world (more on this later on).[16]

From Branching Time to the Thin Red Line

Now, some wish to plug into this model another intuition – that, while at a present time the future is typically open, at a future time what will be the case is going to be settled. This is the gist of TRL. Again, TRL is not a theory about possibility and necessity. It is supposed to spell out our intuitions that the future ahead of us is open, but it still makes sense to claim that we can say true or false things about the future even when contingent events are under the radar. For instance, if I believe on the ground of some present evidence that tomorrow it will be sunny, I am not thereby committed to believe that causation of meteorological phenomena is deterministic or that fatalism is true. TRL and branching time theories share the same tree-like topological structure of time, but the former adds a special entity: the thin red line (R) representing that special future which will be the case. In TRL, a tree-world is a structure $T = <E, <, R>$ such that $\forall e_1 e_2 \in E \cap R\, R(e_1 < e_2 \vee e_2 < e_1)$. Thus, *R* is a history like any other.[17]

[16] One may even add a relation of accessibility among world-tree structures, but we shall not delve into this detail here as it is not relevant to the present discussion.

[17] We will not take into account Belnap and Green alternative view, according to which the thin red line is not simply a history, but rather a function from moments to histories (intuitively, the thin red line of each moment). They introduce this alternative only to discuss a rather technical point but then show that the same problems hold for both versions (for a criticism of Belnap and Green's argument against TRL based on such technical point, see Øhrstrøm 2009). See Belnap and Green (1994): 379–381 and an even more articulated version in Belnap et al. (2001): 162–8.

Belnap et al. (2001) and Belnap and Green (1994) argue against TRL, retorting that it provides an answer to what they call *the assertion problem*, which is problematic for metaphysical reasons (they also lay down semantic arguments against it, but we will address them only indirectly here). The problem moves from the assumption that it is correct to assert only things that at least in principle can be evaluated with respect to the their context of utterance. Of course, this does not mean that the parameters required for the evaluation of the utterance of a sentence must be elements of the context: further 'auxiliary' parameters may be required as well. For instance, in standard semantics, quantified sentences require an 'auxiliary' arbitrary assignment of values to the variables to be evaluated. However, it seems plausible to require that we make an assertion only in case the following conditions are satisfied: either the sentence uttered is *closed by independence*, that is, the truth-value of the utterance does not vary by considering different auxiliary parameters, or the sentence uttered is *closed by context*, that is, the context provides a unique auxiliary parameter (or a unique set of them).[18] For instance, it makes sense to say 'For some x, x is a tea pot', because the variable x is bound, and the sentence does not vary its truth-value with respect to different assignment of values to the variables (the sentence is closed by independence). Similarly, it makes sense to say 'that is a tea pot' pointing to something, because the context provides the referent of 'that' (the sentence is closed by context), whereas it does *not* make sense to assert 'x is a tea pot', since such a sentence is neither closed by context nor by constancy: by uttering it, we are literally asserting nothing.

Now, a sentence such as 'tomorrow will rain' seems to be on a par with 'x is a tea pot'. With respect to auxiliary temporal parameters, which we can think of as the alternative branches that lie *ahead* the time of utterance, its truth-value may vary and thus it is not closed by independence, and if indeterminism is true, it does not seem to be closed under the context either. As Belnap has it (Belnap et al. 2001: 151), there are no facts of the matter fixing one history as *the* history of the context of utterance. Any utterance, as any event, is part of many histories that share the same past but have different future branches. In the context of utterance nothing – or at least nothing that can be read off from the physical conditions together with the physical laws – tells us at which branch we should evaluate the sentence. But then, why does uttering sentences of the form 'Will: p' seems to make sense nonetheless?

Certain philosophers have tried to articulate a defence of the idea that sentences of the form 'Will: p' are indeed closed by independence,[19] but a more attractive position seems to be abandoning the idea that future-tensed sentences are not closed by context. TRL gives precise content to this idea: the future branch that the context

[18] For a formal characterization of the 'auxiliary' parameters, see Belnap et al. (2001): 147. As for the terminology, we rely on Belnap et al. (2001) for 'closed by independence' (what is dubbed 'closed by constancy' in Belnap and Green 1994) and on Belnap and Green (1994) for 'closed by context' (what is dubbed 'closed by initialization' in Belnap et al. 2001).

[19] See McArthur (1974) and Burgess (1978).

of utterance unambiguously set apart for the evaluation of claims about the future is the thin red line. Belnap and Green seem to object to such a solution to the assertion problem mainly because they think it rests on ill-conceived metaphysical grounds.

> [TRL] involves commitments to facts that do not supervene upon any physical, chemical, biological or psychological states of affairs. The fact, if it is one, that at a given indeterministic moment m there is some history such that it is the one that will occur, is not a state of affairs that supervenes upon what is true of particles, tissues or organisms that exist at m. Those of us who do not postulate a Thin Red Line have no need of such a mysterious realm of facts. (Belnap and Green 1994: 380–81; see also Belnap et al. 2001: 168)

> [TRL] also has problem with actuality. […] For a world to be actual is for it to be the world we inhabit. For a history to be actual would be for it to be the history to which the moment we inhabit belongs. It is not, however, in general the case that the expression 'the history to which the moment we inhabit belongs' secures a referent, since uniqueness fails in the face of indeterminism. (Belnap and Green 1994: 380; see also Belnap et al. 2001: 164)

The problems outlined by Belnap and Green are mainly two: (a) TRL requires the possibility of unambiguously referring to our *actual* future, and (b) TRL requires the commitment to metaphysically suspect kind of facts. Now, if (a) were true, then it would follow that branches other than the thin red line are not real alternatives, but merely logical ones (see also the paper by Iacona this volume). Therefore, endorsing TRL would be tantamount to give up the indeterminist view of the future. The way out Belnap and Green suggest (actually, a trap) is to accept ungrounded present facts about the future and thus justify the charge of (b). However, it is not clear that (a) is justified in the first place, and in what follows, we will try to undermine this view. What we believe is that, once the metaphysics underlying Belnap and Green's claim is clarified, nothing is left to support (a) and then (b) but an ungrounded and stubborn intuition.[20]

De re Possible Futures

It is now time to dig into some of the specifics of BTT metaphysics, which will prepare the ground for the discussion of TRL. BTT is a palatable theoretical option because of the way it cashes out the intuition that the future is open. BTT allows us to claim that there is no preferred alternative among the future ones: they are all connected to the present and the past in the same way, and they are all on the same ontological footing. Such an intuition is especially strong in the case of *de re* propositions, where the openness of the future is expressed with respect to the future alternatives for a specific individual. How is this cashed out within the theory in more

[20] It should be clear that Belnap and Green's objection is not concerned with TRL's capacity to propose a solution for the assertion problem. Indeed, they are quite clear on TRL solving the problem, they just object to the solution. 'The […] far more prevalent response to the assertion problem is to hold that future-tensed sentences are closed by context. On this view, future-tensed sentences make reference to a particular history supplied by the context of use – The Thin Red Line. […W]e argue at length against this tempting evasion of the assertion problem.' (Belnap and Green 1994: 378.)

rigorous terms? By simply speaking of instants or moments, we cannot pin that down. However, some events are complex entities, whose constituents/participants are individuals, properties and relations. Thus, the structure of an event has typically the form $e_x = R(i_1 \ldots i_n)$ where $i_1 \ldots i_n$ stand for individuals and R is a n-ary relation.

Now, here is the situation. We have this individual i_t, which exists at a moment t, and we want to say that in the future there are a number of alternatives for it (or her or him). We express that by saying that there are branches in the future of t, containing incompatible events involving i_t. More precisely, there is an individual i_x that is a constituent/participant of an event e_x existing at a future branch b_1 at a moment t_x that *represents* a genuine alternative future for i_t – one among several of its (or her or his) genuine alternative futures. But here we encounter a first ontological issue. Clearly, the intuition is that i_x is the 'same' as i_t; yet this is just sloppy talk. Speaking in more rigorous ontological terms, we should ask the following: are i_t and i_x numerically identical, are they different parts of a same individual, and are they 'cross-temporal counterparts' within the same world or none of these?

This point has not been given close consideration in the literature. Yet, not all of the options may be open to BTT. For the time being, we shall make no assumption, as what we shall say will not depend on this. In the sequel, however, we will not assume that an individual i_f, representing an alternative future for an individual i_m existing at the present moment, is numerically identical to i_m. This assumption may raise further problems that we do not need to address here, and in what follows we will take the representing relations between individuals being analogous to the counterpart relation. One may be tempted to claim that individuals on the thin red line at future times are numerically identical with the individuals in the present that they represent, while individuals on branches other than the thin red line can be at best counterparts of present ones. We think that this temptation should be resisted, since it is not clear that it is compatible with the claim that the thin red line is ontologically and metaphysically on a par with the other branches. And we do not need to defend this problematic thesis in order to argue for the TRL.

We are now in a position to define the alternative futures for individual i_t. In a branching world W, at a moment t, an event e_x taking place on one of the branches is among the *alternative futures for individual* i_t if and only if:

(i) There is an event e_t that is part of t, such that i_t is a constituent of e_t;
(ii) There is an individual i_x which is a constituent of e_x and which *represents* i_t; and
(iii) e_x lies ahead of t. We can, hence, define the *class of all alternative futures for an individual* i_t as that class which includes all the events which are among the alternative futures for an individual i_t. Finally, in order to generate the desired picture, we can partition the class of all alternative futures in subclasses, such that any two events e_x and e_y in the same subclass are not alternative with respect to one another, while any two events e_x and e_y in different subclasses are alternative to one another.[21]

[21] Here we face another problem: the one cashing out a metric to establish whether a class of alternative futures are at the same distance from the present; we shall leave this on a side.

Formal Features of the Thin Red Line

Let us now focus on the main characteristics of the *thin red line*. Intuitively, this branch contains all the truth-makers for future-tensed sentences evaluated at the present. But what sets it apart from any other branch?

Here are a few options that should be ruled out:

(i) It cannot be a different ontological status of its moments to set apart the thin red line from the other branches because, as we have seen, all moments on each branch exist in the same way.

(ii) It cannot be the fact that the thin red line bears a different kind of temporal relation – call it *same-temporality* – to the present than other branches, because there is no such thing within TRL and it would not be easy to justify its introduction if not by claiming that it is an *ad hoc* move.

(iii) Perhaps the right candidate lies among the properties of the thin red line or of its moments. May it be same-worldliness? No; if 'same-worldliness' means 'to be part of the same tree', all events on the trunk and on any branch are same-worldly with the red line.

(iv) May it be actuality? No.[22] Same-worldliness with an actual event implies actuality. Therefore, the thin red line branch is as actual as any other branch.[23] An important consequence of this fact is that if we informally characterize the thin red line as 'what will actually be the case', this expression cannot mean 'the alternative future which is now distinguished by the property of *being actual*'. But of course, not all same-world events (moments) are same-branch events (moments). Yet,

(v) The distinguishing property is not even same-branchness. Indeed, if we evaluate it from the present perspective, past and present events are no less on the same branch with events on the thin red line than they are with events on any other branch.

[22] And, in this opinion, we diverge from Belnap and Green, who argue that TRL 'has troubles with actuality' because it supposes 'that there is one from among the histories flowing out of *m* [the present moment] that is the actual history' (Belnap and Green 1994: 381). We believe that Belnap and Green's understanding of TRL, here, rests on a mistake; there is no reason to maintain that the thin red line is singled out by the property of being actual.

[23] In particular, if there is at least an actual event in a world with a branching structure, then every event in that world is actual and thus every branch. This can be easily demonstrated. (I) Assume there is at least an actual event (intuitively, all present events, including the present instant, are actual). (II) Any same-world event of an actual event is actual. (III) All events (and, hence, moments) on the red line are same-worldly with past and present events (and moments) and with any event (and moment) on any other branch. (IV) Thus, if the events (and moments) in the red line are actual, so are events (and moments) on any other branch. Note that (III) follows from the definition of same-worldliness and (I) and (II) are very plausible constraints on actuality. Thus, the red line branch is as actual as any other branch, independently on how we construe actuality, insofar as (I) and (II) are satisfied.

And here is an answer that strikes us as feasible. The distinction cannot be captured from the 'point of view' of the present.[24] Therefore, we need to distinguish between attribution of same-branchness as assessed at a certain instant and attribution as assessed at a different instant. This requires us to make use of certain semantic distinctions between BTT and TRL – those that in our view are key to pin down the metaphysical edge between BTT and TRL. It should hence be clear that our aim is not to provide a full-blown semantic machinery, but to flash out a certain metaphysical picture. Thus, we shall not spell out the conditions of evaluation of utterances of sentences in a context (as, e.g. Belnap et al. 2001: 141–156 do); rather, we will suggest how to evaluate those propositions pointing at certain features of branching worlds within BTT and TRL. This will allow us to show that the metaphysical objections to TRL are ungrounded, since TRL (a) does not force us to struggle with the notion of actuality and (b) requires only unproblematic facts about the future. And if there are no *metaphysical* objections to TRL, then the assertion problem can be solved by claiming that future-tensed sentences are closed by the context. The semantic rule for evaluating a future-tensed sentence tells us to look at the thin red line as an auxiliary parameter for the evaluation, that is, *the* history of the context of utterance. Of course, being limited to the information that we find in the context of use (the present), we are not in a position to *know* which branch is the red line. But this epistemic impasse is not surprising for auxiliary parameters and should not be confused with a lack of matter of fact.

Now, something should be said regarding our propositions. First of all, they are truth-bearers. And since we want to talk both of BTT and TRL, we allow propositions to have also 'indeterminate' as a truth-value along with truth and falsity. Moreover, for simplicity, we will consider only propositions about (particular) event(s), for instance, the proposition that an event e_x *occurs at a certain moment* m (i.e. an event e_x is part of m) or *that event* e_x *is ahead of event* e_y (i.e. that e_y is part of a moment m_1 and e_x is part of a moment m_x such that $m_1 < m_2$). Since trees and branches are constructed out of moments, which in turn contain events as parts, this makes our job more straightforward.[25] We will also assume this further restriction in order to keep the discussion simple: if $e < e_x$ and $e < e_y$ and neither $e_x < e_y$ nor $e_y < e_x$, then $e_x \neq e_y$ (intuitively, no distinct future branches share some of their events).

We are now ready to consider what it is for certain propositions to be true or false with respect to a world, within BTT or TRL. Here – if we are right – we shall find some relevant distinction between the two theories. The simplest case we will consider is that of a proposition about the occurrence of an event at a certain moment, evaluated with respect to a branch. We will express it through a tenseless temporal operator and a singular term referring to an event. Intuitively, the temporal operator expresses the moment we are looking at when we attribute something to the event (e.g. its

[24] The point we make here can be phrased also within the semantic machinery developed in MacFarlane (2003, 2008).

[25] The main limitation is that we will not have general propositions about events, but this will not affect our point but in one minor respect.

occurring or being in a certain relation with other events). Such a case will be assessed in the same way both in BTT and TRL.

(Truth$_B$) The proposition that, at m, e_x occurs is true in a branch B if and only if e_x is part of m and m is an element of B.[26]

From this basic case, we now develop an account of tenseless operators that involve instants (and not simply moments) and evaluation with respect to tree (and not simply a branch). And, interestingly enough, this makes a difference with respect to whether we are operating in a BTT framework or a TRL. Thus,

(Truth-T_{BTT}) The proposition that at an instant t e_x occurs is true in a tree T, if and only if e_x is part of all moments that constitute t in T; it is false in case it is part of no moment that constitute t in T and is undetermined if it is part of only some of the moments that constitute t in T.

(Truth-T_{TRL}) The proposition that at an instant t e_x occurs is true in a tree T, if and only if (i) e_x is an element of the moment that constitute the thin red line of T at t; it is false otherwise.

It is easy to see that, in TRL, propositions of the form specified will always have classical truth-values (true or false), whereas in BTT, they can be true only if the model has no branch at all (the limiting case of linear time).[27] This may be thought to be a defect of our definition, but actually we cannot avoid this kind of ambiguity if we speak only of instants in a BTT model. The situation gets better if we relativize the *evaluation* of the proposition with respect to a moment, and we still get a different result than in TRL models. Intuitively, the moment of evaluation is the moment we are considering as present when we evaluate the attribution (while the attribution can be made at a different instant than the one at which the moment of evaluation lies).

(Truth-M$_{BTT}$) The proposition that at an instant t e_x occurs is true in a tree T at a moment m, if and only if either $e_x <= m$ or $m < e_x$ and e_x is part of all moments m_x that constitute t in T; it is false in case it is part of no moment m_x that constitute t in T and is undetermined if it is part of only some of the moments m_x that constitute t in T.

(Truth-M$_{TRL}$) The proposition that at an instant t e_x occurs is true in a tree T at a moment m, if and only if either $e_x <= m$ or $m < e_x$ and e_x is an element of the moment that constitute the thin red line of T at t; it is false otherwise.[28]

[26] For an alternative definition of truth at a branch (history), cfr. Thomason (1984).

[27] Given that we have assumed that no distinct branches share any of their events.

[28] The definition suffers from a problem with counterfactual evaluation, as pointed out in Belnap and Green (1994): 380. We shall not deal with this matter here. However, the ontology of possible worlds sketched in the next section below could be put at use to provide a semantic machinery apt to solve the problem.

According to the definition, in BTT, there is a difference between the case in which e_x lies in the past of the moment m we are considering for evaluation and the case in which e_x lies in its future. If e_x lies ahead of m, the situation is as before: we get an undetermined result insofar as we are not in the limiting case of linear time (unless e_x is on none of the branches and thus the proposition is false). But if e_x is in the past of m, then the situation is very similar to that in TRL: we always have a determined truth-value. In TRL, the situation is very similar to the previous one.

More complex cases (connectives and propositions about relations between events) are trickier to spell out, but we do not need to deal with them now, since we just want to give an idea of the semantic notions involved here. Let us then move to consider the cases that we regard as crucial, namely, those concerning attribution of same-branchness to couples of events. The idea is that the difference between BTT and TRL will show up when the instant of attribution and the moment of evaluation are not the same, but the former lies in the future of the latter. Firstly, consider the following claims, as evaluated with respect to a moment m:

1. At t_0, e_2 is on the same branch as e_m.
2. At t_0, e_1 is on the same branch as e_m.

Suppose that e_m is part of m and m is an element of t_0 and e_1 and e_2 are both ahead of e_m. In BTT, insofar as e_m is part of m and m is an element of t_0, both attributions come out true, since e_m is on the same branch with any other event it stands in a temporal relation to. But the same goes in the TRL model. Although we have a distinguished branch in such a model, when we *predicate* a relation of same-branchness between a present event and a future one, we are not in a position to distinguish the thin red line from any other branch, *if* the attribution is made with respect to the present too. Yet the situation changes when the attribution is made with respect to a future instant. Let us consider the following claims:

3. At t, e_2 is on the same branch as e_m.
4. At t, e_1 is on the same branch as e_m.

Suppose that e_m is an event that is part of m and e_1 and e_2 are both ahead of e_m and are parts of (distinct) moments that constitute t.

The instant t is thus future with respect to the moment m, and if we do not have a thin red line in our model, we cannot distinguish among the different moments that constitute t and are temporally connected to m. Therefore, in BTT, insofar as e_1 and e_2 are part of any moment constituting t, e_m is both on the same branch of e_1 and on the same branch of e_2 (although e_1 and e_2 are not on the same branch of each other – remember that same-branchness is not Euclidean – see Fig. 1). Thus, same-branchness attributions 1 and 2 are both true within BTT. The situation changes when we move to a TRL model. In this case, since the attribution is made with respect to an instant t that is future with respect to the time of evaluation, we have a way to tell the situation of e_2, which lies on the thin red line, from that of e_1 which does not. Remember that the evaluations of the attribution are sensitive to what

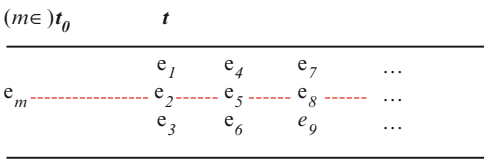

Fig. 1 Illustration of the predication of same-branchness between a present event and some future event, in a TRL model

events we find in the moment that constitutes the thin red line at the instant of attribution.

Here, then, we hit a genuine difference between the two theories.[29] It is not a difference in the very constituents of reality, but in the way our temporal model of reality allows us to assess, at the present time, what *will* be true. To put this into a single expression, we shall say that the exclusive relation among events on the thin red line is *fixed same-branchness*. For any events $e_1, \ldots, e_n$ on the thin red line, any instants t_1 and t_2, any tree T and any moment m on the thin red line, if it is true in T at m that

1. At t_1, $e_1, \ldots, e_n$ are on the same branch
   then, it is also true that in T at m,
2. At t_2, $e_1, \ldots, e_n$ are on the same branch.

Of course, this definition of the characteristic property of the thin red line entails that sentences about the future are closed by context, since it assume that it is possible to settle the truth-value of a sentence in a context with respect to a future point of evaluation 'already' at the time of the context. And this seems precisely what many-branch theories argue against. Belnap, for instance, claims that the context of use of a sentence does not provide enough parameters to determine the (classical) truth-value of it; in particular, it does not permit us to fix a unique history and thus a unique future branch:

> […] Unlike worlds, histories overlap, so that a single speech act will typically belong to many possible histories; and that is why the phrase '*the* history of the speech act' is impermissible. (Belnap et al. 2001: 152, see also Belnap and Green 1994: 378)

Thus, in our definition, the expression for the future moment would not pick up a parameter that can be used to settle the truth-value of what follows.

Yet notice, again, that we are not providing a semantics for tensed sentence here, but rather we are defining a property of a history (a maximal chain of moments) that, in our model of reality, distinguishes it from any other history at the same tree.

[29] It is noteworthy that the analysis does not depend on whether one adopts a tensed or a tenseless language. Indeed, 'e_1 will be on the same branch than e_2', when evaluated at t, is still F for TRL and *Ind* for BTT.

(Incidentally, that is why we speak of propositions as evaluated with respect to a time, and a world, rather than of utterance of sentences in a context – we consider all indexical completion from the context unproblematic with respect to *any* temporal parameter, whether future or past.) Remember that we are not assuming anything about any distinction between the past and the future, other than the topological asymmetry in the temporal relation, as in the very spirit of the standard formulation of BTT. Therefore, *any* moment in time is on the same footing as any other. There may thus be *semantic* reasons to deny that there are no matter of facts in the context of utterance concerning *the* future history to which a certain moment belong, but from a metaphysical point of view, we are legitimate to have a 'God's eye' view over the whole tree-world. The tree-world plus the thin red line is a model through which we aim at catching a certain picture of how reality is like.[30] From an epistemic point of view, we could never be in a situation of knowing what events will be on the red line (more realistically, we may know that certain events are more probable than others), but this does not thwart us from fleshing out a *metaphysical* notion. Hence, from *this* point of view – the God's eye – the notion of fixed same-branchness is well-defined and well behaving, and its use can be impinged by no *semantic* (or *epistemic*) argument.

This does not settle the issue in favour of the TRL once and for all, because there are still serious objections to it. In other words, the definition of the thin red line in term of fixed same- branchness is still a formal characterization of the model, which does not get us what we are after: a full-blooded metaphysical view. In particular, what is still unclear is what *makes it the case* that a certain branch is the thin red line, that is, that the relation among events on it is *fixed same-branchness*, and whether it is possible to answer this question while being coherent with other assumptions on the theory, such as the ontological indistinctness of the TRL with respect to other branches and in general the openness of the future. In the sequel, we will aim at acquiescing those further worries.

Branches, Possible Worlds and Determinacy

We are at this point ready to address questions regarding the different ways in which BTT and TRL express different forms of metaphysical possibility. Intuitively, each branch of a tree T represents a metaphysical possibility. But this should not be taken literally. As we stressed above, here we are not dealing with a usual notion of possibility: all T's branches are part of the same world and they exist in the same way. Here is, then, our first question: more exactly, what is the link between the branches of T and a standard (branchless) possible world?

[30] Even Belnap et al. (2001) clearly distinguish between the metaphysical picture and the semantic treatment of tensed sentences based on such picture.

The answer is quite straightforward. For each branch of a tree *T* and its 'trunk' (i.e. for each history), there is a branchless quasi-standard[31] possible world, which *maps* it. This is the world that contains exactly all and only the events on the trunk *and* the branch. To be more precise, a quasi-standard world (from now on, a world) is a structure $w = <E$, such that for any two events e_1 and e_2 included in *E*, either $e_1 > e_2$ or $e_2 > e_1$. Call *W* the class of all quasi-standard worlds.

Now, for any tree-world *T*, there corresponds a set of possible worlds *w*, which *maps T*. That is the set of worlds such that any branch of *T* is mapped by an element of *w*, and *w* contains only members that map a branch of *T*. Also, for any tree *T* containing a thin red line, there is an immediate correspondence between the thin red line and a world *W*. That is, to $T = <E, >, R >$ corresponds $w = <R$, Ð.

As we see it, the discussion surrounding BTT and TRL often rests on a confusion between three different kinds of necessity and determinacy. Having clarified the relation between standard possible worlds and trees in BTT and TRL, we are in a position to sort out these kinds, which we will put at use in the sequel:

(i) First, there is that notion of necessity corresponding to textbook possible-worlds semantics necessity, according to which *a proposition is necessary simpliciter when it is true in* w *for all the members of* W (the class of all worlds).

(ii) Second, there is necessity within a tree-world. Most trees do not contain all metaphysical possibilities, and yet there is a sense in which one could say that a certain proposition is necessary within that tree-world: this is the case when the proposition is true with respect to all the branches and the trunk. Thus, we say that *a proposition is necessary (with respect) to a tree-world T when it is true at every branch and the trunk in T or, alternatively, when it is true with respect to all worlds included in the set of worlds that maps T*. Coincidentally, this is what BTT theorists call *being determinate* of a proposition with respect to a tree.[32]

(iii) Finally, *a proposition is determined with respect to a branch when, at that branch, the proposition is either true or false*.

Clearly, necessity with respect to a tree and determinacy with respect to a branch are quite different from necessity simpliciter. Contingent claim, such as

3. Humphrey is elected president in 1968,

is not necessary in sense (i) even though they are determined with respect to a branch. Which is to say, at a quasi-standard world, (3) is determined, despite its

[31] We call such worlds 'quasi-standard' as they are defined in terms of their constituting events and the temporal relations between them, which of course is not the way they are defined in a textbook possible-worlds semantics.

[32] The notion of necessity with respect to a tree-world is defined formally; what does it boil down to on a more substantial level depends of course on how we construe the alternatives on the branches. If they are nomologic alternatives, then necessity with respect to a tree-world is physical necessity. An alternative is construing the branches as the metaphysical alternatives *at a time t*. We will thus have a notion of temporal necessity (parasitic on that of metaphysically possible at a time *t*) distinct both to physical necessity and necessity *simpliciter*.

being contingent. Note also that while BTT theorist speak of being *determinate* with respect to a tree, we speak of being *determined* with respect to a branch, in order to stress the fact that determinacy with respect to a branch is not a metaphysically loaded notion, while determinacy with respect to a tree is at least potentially so. For instance, if we construe the branches as metaphysical alternatives at a time, then a proposition is determinate at *t* if it is true on every branch of the tree, that is, if it is *metaphysically necessary with respect to a time t* (see note 28). And if we construe the branches as nomological alternative futures of *t*, then a proposition is determinate at *t* if it is true on every branch of the tree, that is, if it is *physically necessary with respect to a time t*. But independently on how we construe future alternatives, being determined with respect to one of these merely means possessing a 'traditional truth-value' (viz. true or false, but neither both, none of them nor some other) with respect to it.

Finally, (i)–(iii) are valid both in BTT and TRL. Within TRL, however, we can distinguish one more sense of determinacy – determinacy with respect to a tree, which can be defined as follows:

(iv) *A proposition is determined with respect to a tree T which contains a thin red line when, on the thin red line, that proposition is either fixedly true or fixedly false* (i.e. true or false with respect to each moment on the thin red line).[33]

Of course, that a proposition is determined with respect to a tree does not entail that it is necessary *simpliciter* nor that it is necessary at that tree (i.e. determinate with respect to that tree). For a proposition, being determined with respect to a tree (with a thin red line) is as metaphysically light as it is being determined with respect to a branch: it merely means possessing a traditional truth-value with respect to a (moment in) that tree.[34]

Brute Facts

In this section, we shall take stock of what we said so far and draw some conclusions regarding Belnap and Green's claim that TRL is – metaphysically speaking – ill-founded. First of all, does TRL compel to some form of determinism? We think it does not. On the one hand, TRL is compatible with the thesis that what future states the universe will be in is implied by what states it has been in; all you need to

[33] Although this sense of determinacy is not used in the rest of this chapter, it may come in handy when considering whether TRL can accommodate cases of backward causation. We believe that it can – contrary to Miller (2008, 2005) – although we shall not argue for this point here.

[34] The distinction that Von Wright (1984) makes between *truth* and *determinate truth* (see also Iacona this volume) corresponds to our distinction between *being determined with respect to a tree* and *being necessary (i.e. determinate) with respect to a tree*. According to Von Wright, a future-tensed proposition can be true without being determinately true, that is, it can be true at the present time without being true in *every* future alternative. This holds also in our picture.

do is to commit to interpreting all branches as mere representations of epistemic possibilities, while claiming that the thin red line also represents the only genuine possibility at that tree. (As we specified in the opening remarks, however, a determinist may hold that there are other trees where, because of different initial conditions, the thin red line lies on a branch other than the branch where it lies at the actual tree.) Yet, this is not to say that TRL entails determinism. Indeed, TRL is compatible with indeterminism too. After all, it maintains that true claims regarding the future do not need to be true with respect to every branch, that is, determinate with respect to that tree. But the relationship between TRL and determinism gets even more puzzling when we add that neither determinists nor indeterminists typically will invoke TRL to shape up their positions. You can have branches and still be a determinist, yet determinists do not need branches, as they can have a linear version of time. And while a branching time structure comes handy to many indeterminists, these would usually deny the existence of a thin red line.[35] Thus, you can have a thin red line and still be an indeterminist, but most indeterminists will not include thin red lines within their representations of temporal structures. Thus, TRL is somewhat puzzling: it is midway between determinism and indeterminism, being compatible with both and at the same time not a standard leeway to both. So, under which assumptions does TRL become an appealing position?

In our view, TRL is appealing to those who hold an *indeterminist view of natural laws* (plausibly along with a probabilistic conception of causation) *while at the same time not wanting to give up the idea that the future is not metaphysically distinct from the past and the present*. Given certain present conditions and a set of probabilistic natural laws applying to them, in most cases, there will be two or more alternative possible futures, each of which is assigned a certain probability of being the case. In this scenario, each branch represents one of the possible futures. However, the laws are compatible with the thesis that *only one* of the alternative possibilities will be the future: at present time, we have some genuine metaphysical alternatives, but we know that, at a future time, only one of them will be *the* future (of our world). Well, the thin red line helps sorting out all of this, as it clearly distinguishes between the evaluations of a proposition at present time from the evaluation that we can foresee it will receive at a future time.

But now the question arises: what makes it determined that only a certain future will hold, while many are genuinely possible at this time? In other words, what justifies us in positing the existence of the thin red line? It cannot be some metaphysical property of one of the branches that tell it apart from the other branches, because we said that all branches are actual and 'real' in the same way. Yet it cannot be the physical laws either, because otherwise TRL would not be compatible with indeterminism. Indeed, in the preferred reading, the branches stand for physically possible alternative futures, that is, those in such future states that are compatible with the present state, without being necessitated by it. Thus, indeterministic physical laws cannot ground a thin red line.

[35] An exception is McCall (1984).

Taking a different perspective, one could argue that, although physical laws do not logically entail the existence of a thin red line, they *motivate* TRL. Of course, such laws may induce to opposite upshots, but we find reasonable to ground TRL on them. Indeed, probabilistic theories force us to a particular conception of causality, which in turn requires (or at least is more 'tuned with') a branching view of time (space-time). According to the probabilistic conception, there may be (and often there are) more than one effect associated to a single cause. This is where the concept of indeterministic causation diverges from the deterministic one (and probably from the 'naïve' one too). However, the probabilistic conception does not diverge from the deterministic (and 'naïve') conception under another respect: no matter how many future effects are probabilistically associated with one cause, it will bring about only *one* effect. That is, probabilistic theories do not force us to maintain that one cause will follow more than one effect *in our world*.[36] And neither forces us to deny that it is now true (or false) that a certain future alternative will occur rather than another, insofar as this is not a consequence of the state of the universe up to the present plus the physical laws. For example, it is a matter of chance whether, at a future time *t*, an offspring *o* of individuals *a* and *b* will inherit *a*'s or *b*'s genetic make-up with respect to a specific *locus*. Still, it seems plausible to regard as true *now* that, at *t*, the locus will be filled with a specific make-up, and we could see this fact as implying (i) that, at present, there is more than one genuine alternative metaphysical possibility and (ii) that, at present, it is true that at a future time we will see the issue as settled, although at present we have no epistemic access as to how it is going to be settled. This is simply a consequence of the fact that our present spatiotemporal position is *not privileged* with respect to past or future ones. When described from a later temporal perspective, what looks as unsettled (given all, we can know of the past and the present) is indeed settled. The present truth of many future-tensed propositions is thus only a consequence of *what will occur*, which from a 'God's eye' point of view is as settled as what occurred. This is the intuition that the TRL wants to preserve and which is not at all in disparity with indeterminism: the future is not only as settled as the past; it is also as *contingently settled* as the past. Actually, thus, one could argue that indeterministic physical laws are best explained when we posit a thin red line.

Yet, of course, the issue is debatable. One man's reason is another man's *reductio*. One could rebut that the fact that physical laws are best explained when we posit a thin red line is a problem we should debug, not a virtue of the theory. Physical laws are merely compatible with a thin red line, and there is nothing in the world that can determine which among the possible histories *is* the thin red line. Hence, the postulation of a thin red line is at the end of the day groundless (Belnap et al. 2001: 169).

The last resort for a supporter of TRL is to go the hard way: the thin red line boils down to a *brute fact* about the world. Now, although brute facts may come off as metaphysically repugnant, they do not necessarily mean bad metaphysics and there

[36] Even if we accept a multiverse, in each single world one effect follows. See Lockwood (2005).

may be philosophers who are willing to accept an ungrounded thin red line.[37] After all, such facts do not seem to 'point' behind what is at the theorist's disposal – as Ted Sider has argued with respect to certain primitive properties – thereby ending up being scientifically unacceptable. We normally accept as a brute fact about the past that certain things rather than others have happened. If we ask 'what ground those facts?' *and* we are not determinist (or fatalist), all we can do is waive our hands in the air. But if the BTT theorist cannot be blamed for admitting brute facts concerning the past, then why should the TRL theorist be blamed for admitting brute facts concerning the whole of time? Any rationale for distinguishing the two cases seem to require that we resort to a difference between past and future that goes behind their different topological outline, which would be going behind the aims of BTT. In conclusion, the brute facts that seem at bottom to ground the thin red line are of a kind that *any* philosopher who is both eternalist and indeterminist is compelled (and usually willing) to accept. A BTT theorist who does not want to tangle with metaphysical differences between past and future should remember that she has little ground to accept such facts with respect to the past and present, but not with respect to the future. In an eternalist framework, the facts that ground the thin red line do not constitute a 'mysterious realm of facts'; indeed, what would be mysterious is a distinction between the past and the future of this sort.

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[37] See the paper by Iacona (this volume): 'Perhaps there is nothing in the structure of the world that determines a single possibility to be actual, yet this does not prevent that possibility from being actual' (p. 41).

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