(In)determinism, Branching Time, and Branching Space

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Abstract: The branching time analysis grounds the possibilities entailed by temporal indeterminism in a branching temporal structure. I construct a spatial analog of the branching time analysis – the branching space analysis – according to which the possibilities entailed by spatial indeterminism are grounded in branching spatial structure. The construction proceeds in such a way as to show the analogies between the branching space and branching time analyses. I argue that the two views are a package. In particular: the theoretical virtues of the one are theoretical virtues of the other and so if one ought to be accepted, then the other should also be accepted. And: if one ought to be denied, then the other ought to be denied as well. Thus, the branching space analysis functions either as a counterexample to the reductive strategy embodied in the branching time analysis or as a reasonable extension of it – as a lesson learned from it.

Keywords: branching time, indeterminism, modality, time, space

1.1: Introduction

Temporal determinism is (somewhat roughly) the thesis that every moment is such that, given the state of things at that moment and the laws of nature, the state of things at every other moment is necessitated.[1] Temporal determinism is false – i.e. temporal indeterminism is true – if and only if there is at least one moment such that there are alternative possibilities for its state (given other moments). The branching time analysis grounds these possibilities by postulating a branching temporal structure on the collection of moments.[2]

In this paper, I construct a spatial analog of the branching time analysis – the branching space analysis. Spatial determinism is (somewhat roughly) the thesis that every region is such that, given the state of things at that region and the laws of nature, the state of things at every other region is necessitated.[3] Spatial determinism is false – i.e. spatial indeterminism is true – if and only if there is at

[1] In what follows, I will suppress explicit reference to the laws of nature in specifying the relevant possibilities.
[2] See (Belnap et. al 2001), (MacFarlane 2003), (McCall 1976), (Prior 1967) for canonical discussion.
[3] Spatial determinism is rarely discussed, though some suggest that the spatial (in)determinism's truth plays a role in differentiating time and space. For example, Craig Callender has recently argued that "time is that direction [on the

least one region such that there are alternative possibilities for its state (given other regions). The branching space analysis would ground these possibilities by postulating a branching spatial structure on collections of regions.

Part of the purpose of the paper is imaginative: to begin exploring an interesting possibility. But I am also interested in using the spatial analog as a probe for thinking about the branching time analysis. As to the all-things-considered plausibility of the analyses, I express no judgment. Instead, the argument is conditional: the two analyses are a package. Reasons for the one are reasons for the other. And if we ought to reject one, we ought to reject the other. Thus the paper has a polemical purpose, as well an imaginative one.

If the analyses are a package and the branching space analysis is too startling to accept, we ought to doubt the branching time analysis. If so, the branching space analysis would constitute a kind of counterexample for the reductive strategy embodied in the branching time analysis. But maybe the branching space analysis will turn out to be no less acceptable than the branching time analysis. Then: we have learned something from accepting the branching time analysis – that The World has a branching spatial structure.

Mostly, the case for extending the branching time analysis to the case of spatial determinism rests on the analogies between the two cases. These analogies entail that virtues of the one are virtues of the other – some of them anyway. The parallel constructions show the relevant analogies and so a discussion of the details will have to wait.

Of course, there are differences between space and time. It may be that there are barriers to a branching space analysis that don't exist in the case of temporal determinism. Thus there is logical room for doubt about the branching space analysis, but optimism about the branching time analysis. But this combination of attitudes is precarious.

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manifold of events] in which our theories can obtain as much determinism as possible" (Callender 2008: 1). Also see (Skow 2007), and (Huggett 2010: 104-105).

Doubts about one view are likely to provoke rational doubt about the other. Suppose that we have determined that the spatial analysis is false. It may be that our reason for our doubt is a consequence of spatiality's possession of some feature that temporality lacks. Even so, the possibilities entailed by spatial indeterminism have *some* account. But, given the structural similarities between space and time as well as the similarities between spatial and temporal indeterminism, such an account will provide a model for a rival to the branching time analysis.[4]

1.2: Introduction: Branching Time and Intentionality

The metaphysics is interesting on its own, but part of its importance of stems from the semantic consequences that have been thought to follow from accepting that The World has a branching temporal structure. In short: indeterminism has been thought to entail semantic indeterminacy. Belnap et al. put it like this:

> Indeterminism, however, compels … [the view that when] you utter something, you do not thereby uniquely determine the entire future course of history. Your utterance has many choices and chances ahead of it, and so belongs to many histories. The context of use determines a unique moment, but not a unique history. (Belnap et al. 2001: 232)

This is the root of the problem. MacFarlane develops this point and draws the semantic conclusion[5]:

> Suppose that at some moment m_0 there is an objectively possible history h_1 in which there is a sea battle the next day, and another h_2 in which there is no sea battle the next day… Now suppose that at m_0 Jake asserts 'there will be a sea battle tomorrow'. Is his utterance true or false? His utterance takes place at m_0, which belongs to both h_1 and h_2. In h_1 there is a sea battle the day after m_0 while in h_2 there is not. We may assume there is nothing about Jake's intentions that picks out a particular history (h_1 or h_2). Jake may take himself to be making a claim about 'the actual future history', but if this means 'the future history that includes this utterance [as part of its past]', then it is an improper definite description. There is no such unique history. Given that nothing about the context of utterance singles out one of the histories of which it is a part, symmetry considerations seem to rule out saying either that the

[4] See (Deutsche 1990) for an example of what the resulting analysis of the possibilities entailed by temporal indeterminism might look like.

[5] MacFarlane ends up rejecting the argument, but does so by revising its semantic assumptions. He thus thinks that its metaphysical component is sound and constrains our understanding of semantics.

> utterance is true or that the utterance is false. Thus, it seems, we must count it neither true nor false. (MacFarlane 2002: 323)

The argument here consists of two components: a metaphysical component expressing the branching time analysis and a semantic component. If the branching time analysis is true, then on the assumption that determinism is false, the semantics of future-tensed sentences like the sentence (1) 'There will be a sea battle tomorrow' is problematic. If (1) is neither true nor false, then it would seem that either it expresses no proposition (assuming propositions are necessarily truth-valued) or we will have to allow the existence of truth-valueless propositions. We'll have to exercise some cleverness to make sense of the use of future-tensed expressions in truth-functional contexts. We'll have to trouble with explaining why a truth-valueless sentence might nonetheless be assertible. Moreover, it is strange that today's assertion of (1) could lack a truth value, when tomorrow, "when we are in the midst of a sea battle, it surely seems that my earlier assertion (1) was true at the time of utterance" (Brogaard 2007: 327).[6]

If it should turn out that the branching space analysis is a kind of counterexample to the branching time analysis, then this will do some work toward dissolving the semantic puzzles on which Brogaard, Belnap, and Macfarlane (among others) are focused. For then indeterminism would not give us reason to think that the present moment is part of more than one history.

Alternatively, if the branching space analysis is a lesson we learn from the branching time analysis, then we face spatial analogs of the semantic puzzles generated by the branching time analysis. Given that the situation here does not determine the situation over there and the branching space analysis is true, this locale is part of many spaces. Then: our speaking and thinking about distant regions will fail to bear on a unique truth-maker - if the branching space analysis is true. It seems, therefore, as if these thoughts and assertions cannot be counted as either true or false.

[6] For some representative discussions see (Thomason 1970), (Thomason 2002), (Belnap et. al 2001), (Belnap & Perloff 2011), (MacFarlane 2003), (Brogaard 2008), and (Besson & Hattiangadi 2014). Consult (Øhrstrøm & Hasle 2011) for an excellent overview.

In what follows, I set aside the semantic issues and will not evaluate the claim that indeterminism would entail semantic indeterminacy. Instead, I focus on the metaphysics.[7]

2.1: The Branching Time Analysis: The Basic Relata

The branching time analysis grounds the possibilities entailed by temporal indeterminism in a distinctive pattern of (dis)connection among the moments that are supposed to constitute the temporal extent of The World.[8] According to it, if temporal indeterminism is true, The World has a branching temporal structure.

The World exhausts the whole of reality and is a fusion of all and everything that exists (anywhere or anywhen). The parts of The World include: the 1970s, me (and any of my parts), Seattle, etc.[9] Thus, The World is maximally extended both spatially and temporally at least in the following sense: since everything is part of The World, there is nothing that can be truly said to exist at any time or place that is not part of it.[10]

The literature on branching time typically begins by postulating a partition of The World into moments and branching temporal relations defined on them. **Moments** are supposed to be all and only everything existing at a time. Thus, they are supposed to be spatially maximal and temporally minimal – lacking any temporal extent. The existence of moments would enable an elegant picture of The World: The temporal extent of The World is constituted by relations among moments and the spatial aspects of The World are constituted by spatial relations among the parts of moments.[11]

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[7] See (Barnes and Cameron 2009) and (Barnes and Cameron 2011) for a slightly different take on some of the big picture issues in the vicinity.

[8] My sketch of the analysis mostly follows (Belnap et al. 2001). I depart from their presentation in two chief ways: (i) I use mereological concepts where possible; and (ii) I replace their order-theoretic vocabulary.

[9] Whether *abstracta* are also parts of The World, I leave as an open question.

[10] Some have doubted that there is or could be such a thing as The World (Van Fraassen 1995) (Simons 2003). See (Varzi 2006) for a defense of the notion.

[11] This is the so-called Galilean spacetime of (Earman 1970). See also pages 202-204 of (Sklar 1974) for a lucid discussion.

The chief thing to know about moments is this: Two things are parts of one moment if and only if they are simultaneous with each other.[12] It follows from this that there is one way in which moments are point-like. They are temporally atomic. That is: a moment has no parts such that some are later than others. The parts of a moment are all mutually simultaneous. Moments are also supposed to point-like in a second way. Moments are supposed to be temporally un-extended – i.e. the World's temporal extent is not determined by the cardinality of the set of all the moments there are.[13]

But the postulation of moments is epistemically risky. First, simultaneity is trouble. The postulation of moments would seem to involve an assumption of absolute simultaneity. Our best science of motion rules out attributing absolute simultaneity to spatially separated things. So it would appear that a metaphysic that postulates moments is inconsistent with our best science.[14,15]

Second, moments exist only if The World is not temporally gunky.[16] Something is gunky if it has no smallest parts. The World is temporally gunky if and only if any temporal part of the world also has temporal parts. But moments are supposed to be temporal atoms and have no temporal parts. Thus, if there are moments, then some temporal parts of The World have no further temporal parts.

Finally, it is possible to harbor doubts about whether The World has a partition into temporally un-extended parts. Clearly, if The World has no temporal atoms, then it has no temporal atoms that are un-extended. But it is also possible to harbor independent doubts about whether The World has a

[12] We might be tempted to reduce simultaneity to spatial connection. Suppose, as on the Neo-Newtonian picture, that only simultaneous things might be strongly spatially connected. Then we might hypothesize: two things are parts of a moment if and only if they are strongly spatially connected.

[13] If something lacks temporal extent, then it is a temporal atom. Thus if something is point-like in the second way, it is point-like in the first way. Therefore, if The World has a partition into temporally un-extended parts, then it also has a partition into temporal atoms. I am not sure about the entailments in the other direction. It seems plausible to suppose that moments' lack of temporal extent would follow from their lack of a partition into T-related parts. But I do not presume to know.

[14] See (Huggett 2010), (Maudlin 2012), and (Sklar 1974).

[15] See (Belnap 1992) for a discussion of the issue as it affects the branching time analysis.

[16] See (Zimmerman 1996) for a bit of historical survey of gunk. McTaggart also affirms the universe is temporally gunky (McTaggart 1921: 176). Thanks to Alex Skiles for the reference to McTaggart.

partition into temporally un-extended parts. Maybe, for example, there are temporal atoms, but all of them have some temporal extent.[17]

Despite these risks, I will proceed in terms of moments. Partly this is for the sake of tradition, but it is also because following the tradition tremendously simplifies the discussion – at least until we have our bearings. For example, it greatly reduces mereological perplexities. At any rate, as Belnap et al. note, a metaphysic that includes moments is an "approximation of the truth, and may give us some insight into how our world hangs together" (Belnap et al. 2001: 178).

2.2: The Branching Time Analysis: Temporal Indeterminism

The branching time analysis is the product of an attempt to explain something – namely, being possible in a certain way. Before we get into the details of that explanation, it will benefit us to get a clearer grip on the object of that explanation. Doing so will enable us to understand why the branching time analysis has the structure it has (thereby paving the way for the branching space analysis).

Temporal determinism is true if and only if each moment necessitates every other moment lying in its past or future. One moment m_1 necessitates another if and only if the other is necessitated (given m_1). One moment is necessitated (given another) if and only if the intrinsic qualitative state of the one is necessitated (given the other).[18] Thus, if a moment m_1 is necessitated (given another moment m_2), there is some intrinsic state S such that m_1 is S and it is not possible (given m_2) that m_1 not be S.

Let 'Tαβ' express the relation things have when one thing is temporally prior to another. Consider, for example, a moment today m_1 and a moment tomorrow m_2. Then: Tm_1m_2 and ~Tm_2m_1.

[17] (Zimmerman 1996) also discusses this issue. It is sometimes suggested by physicists that time is not continuous - but composed of discrete, extended intervals (Yang 1947). Thanks to Peter Ludlow for the reference.

[18] The intrinsic qualitative state of something is intrinsic to it and also qualitative. A qualitative state is one that may be shared by numerically distinct things. Thus, for example, Obama and his perfect twin might each instantiate the same qualitative state. I will not provide an account of what constitutes a feature as an intrinsic one. In what follows, I suppress explicit qualification by 'qualitative' or 'intrinsic'.

Two moments $\{m_1, m_2\}$ are **strongly temporally connected** if and only if either Tm_1m_2 or Tm_2m_1. Then we may define temporal determinism as follows:

Temporal determinism is true if and only if:

> There are at least two moments $\{m_1$ and $m_2\}$ and intrinsic qualitative states $\{S_1$ and $S_2\}$ such that: (i) m_1 is S_1 and m_2 is S_2, (ii) m_1 and m_2 are strongly temporally connected, and (iii) it is not possible (given that m_1 is S_1) that m_2 not be S_2.

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Therefore, if temporal indeterminism is true, there is at least one moment m_1 the state of which is contingent (given a moment m_2 to which m_1 is strongly temporally connected). There are two possibilities (given m_2) for m_1: that it be the way it is and that it not be this way.

It is useful to have terminology that allows us to speak somewhat abstractly about things related in this way. In any case in which there is a possibility (given some *x*) for some *y*, *x* is a **gift** for y and *y* is a **target** of x. (Depending on expository needs, I'll sometimes articulate the relevant relations as follows: '_ is a target of a gift' or '_ is a target of a possibility'; or '_ is a gift for a target' or '_ is a gift for a possibility'.) Thus, if temporal indeterminism is true, there are two moments $\{m_1$ and $m_2\}$ such that: m_1 is a gift and m_2 is a target, m_2 is a target of m_1, and m_2 is a target of two alternative possibilities (given m_1).

Suppose, for example, that it was possible (given the state of things at the beginning of 1965) that there would be a Nordic-style welfare state in the United States at the beginning of 2000. Then: the beginning of 2000 is a target of a possibility. The beginning of 1965 is a gift for a possibility – i.e. that there would be a Nordic-style welfare state in the United States at the beginning of 2000. The beginning of 1965 is a gift for 2000.

2.3: The Branching Time Analysis: Branching Time

Temporal indeterminism would entail the existence of moments that are the targets of alternative possibilities (given moments in their past or future). The branching time analysis is supposed to provide an account of what constitutes a possibility (given a gift) for a target. It would ground these possibilities by postulating the existence of counterparts for targets of gifts. For each alternative possibility (given a gift) for a target of that gift, the branching analysis postulates the existence of a counterpart for that target.[19] If a target of a gift has no counterparts, then the target could not have differed (given the gift). Wherever there are counterparts there are alternative possibilities and wherever there are alternative possibilities there are counterparts.

In virtue of what do counterparts ground the relevant modal facts? What makes a counterpart a counterpart?

Temporal Counterparts

For any {*c*, *t*, and *g*} such that *t* is a target of *g*:

c is a temporal counterpart of *t*

if and only if

(i) *c* differs intrinsically from *t*;

&

(ii) *c* and *t* are not strongly temporally connected ;

&

[19] The fact that I will later discuss the spatial case suggests that things might be clearer if I used the expression 'temporal counterpart' to distinguish from 'spatial counterpart'. But these expressions are unbearably awkward and context makes the relevant distinction clear enough. Accordingly, I'll use the longer expressions only when necessary, leaving it up to context otherwise.

(iiia) if T*gt*, then T*gc* and for any moment *m* such that T*mt* and T*gm*: T*mc*;

&

(iiib) if T*tg*, then T*cg* and for any moment *m* such that T*tm* and T*mg*: T*cm*.

Note some immediate consequences: Each member of a target-counterpart pair is a counterpart for the other. The counterpart-of relation is symmetrical.

What purposes are served by stipulating that counterparts have these features? What work do these clauses perform?

Clause i requires that targets and counterparts differ with respect to their intrinsic qualitative states. Counterparts ground possibilities by differing qualitatively from their targets. A counterpart of a target grounds the possibility that the target lack some feature by lacking that feature. This reflects the fact that the branching analysis is an instance of **detaching reductionism**. Such accounts ground the possibility that something *could* have had some feature by postulating the existence of something that *does* have that feature.[20] A target could have had such-and-such feature because there is something that does have that feature. The chief appeal of detaching reductionism is this: something's having a feature entails that it could have had that feature. Detaching reductionism generalizes this: even if the possibility that a thing has a feature is counter-factual, the detaching reductionist aims to ground this possibility in something's having that feature.

Why clause ii? Why postulate a disconnection between targets and their counterparts? Detaching reductionism runs the risk of incoherence. If there are mutually incompatible possibilities and we are to understand the possibility that something *could* have had some feature by postulating the existence of something that *does* have that feature, we need to postulate some mechanism to preserve the coherence of the whole of reality. Consider David Lewis' account. Lewis postulates the existence of a plurality of objects called 'worlds'. Given that it is contingent that I am awake, there is a world

[20] David Lewis (1986) provides the most prominent version of detaching reductionism.

relative to which I am awake (i.e. the actual world) and a world relative to which I am not awake. The world relative to which I am not awake is a counterpart for this world. Its existence grounds the possibility that I might not have been awake. On Lewis' account, the coherence of the whole of reality is secured by the fact that each world is utterly spatio-temporally disconnected from every other world. No two things such that one is part of one world and the other is part of another world have any sort of spatial or temporal connection to one another. Thus, there is no world relative to which I am both awake and not awake.

Similarly, the branching time analysis secures the coherence of the whole of reality by postulating a disconnection between counterparts. Thus clause ii requires a disconnection between the counterparts that the branching time analysis postulates. If it is possible that tomorrow there will be a sea battle and possible that tomorrow there will be a peaceful cruise, it is not as if there will be a pleasure barge cruising awkwardly through a bloody sea battle – as if the battle and cruise were competing for the same space. Each is disconnected from the other both temporally and spatially.[21]

Moreover, like Lewis, advocates of the branching time analysis postulate the existence of extended instances of coherence. Lewis calls these 'worlds'. On the branching time metaphysic, these are histories. A **history** is a whole composed all and only of moments that are mutually strongly temporally connected.[22]

Thus histories are paths across the entire temporal extent of The World (assuming that it has an entire temporal extent). And it is only relative to a history that things have historical properties. For example, relative to one history there will be a sea-battle tomorrow and relative to another there will not.[23]

[21] Distinct moments are supposed to be spatially disconnected: nothing that is part of more than one moment has any spatial connection to anything that is part of another moment.
[22] …and, derivatively, of the parts of those moments.
[23] Hence the familiar semantic puzzles about branching time.

The iii-clauses perform two functions. First, a counterpart and target need to be exactly similarly temporally related to their gift. The iii-clauses specify the sense in which counterparts are similarly situated with respect to their gift. Second, the iii-clauses also require that counterparts not be utterly disconnected from one another: they are not strongly temporally connected, but they are **weakly temporally connected** via their gift.

Consider the first function. The branching time analysis insists that for any {*t*, *c*, and *g*} such that *t* is a target of *g* and *c* is a counterpart of *t*: *t* is strongly temporally connected to *g* and *c* is strongly temporally connected to *g*. One required similarity between counterparts is that each be strongly temporally connected to their gift. But this is not sufficient.[24]

To see what is needed, consider some light bulb and suppose that it is possible (given the state of things at m_1) that ten minutes after m_1 the light bulb be on and that it is possible (given the state of things at m_1) that ten minutes after m_1 the light bulb not be on. Then, on the branching time analysis, there needs be some counterparts m_2 and m_3 such that m_1 is ten minutes prior to each. The moments m_2 and m_3 are counterparts for each other because they are each ten minutes after their gift.

But the concrete relation here is but one way in which targets and their counterparts might be strongly temporally connected to their gifts. For example, there is the familiar fact that moments might be strongly connected by temporal distances of less than ten minutes. More exotically, (for all I know) histories might lack a well-defined metric. There might be some moments that are strongly temporally connected, but not in such a way that there exists a determinate measure of their temporal separation. These moments would be temporally distinguished simply by their position in the temporal order. What is needed is some notion of same-timed-ness that applies to counterparts, even when there is no determinate measure of their temporal distance from their gift.

[24] Or else temporal indeterminism might follow from the simple fact that The World is varied across its temporal extent.

The iii-clauses require that the histories of counterparts overlap between themselves and their gifts. Thus counterparts for targets of a gift are same-timed in the sense that there could be no more temporal distance between one counterpart and the gift than between the other counterparts and the gift.

In virtue of the way in which the iii-clauses define similarity of situated-ness among counterparts, they require that counterparts of targets of a gift be strongly temporally connected to that gift. It is this that generates the entailment from temporal indeterminism to the thesis that The World has a branching temporal structure. If counterparts are not mutually strongly temporally connected (as clause ii requires) but counterparts are temporally strongly connected to their shared gift (as the iii-clauses require), then if there are counterparts, The World has a branching temporal structure. Thus, if the branching time analysis is true and temporal indeterminism is true, The World has a branching temporal structure and there is more than one history.

The thesis that counterparts are strongly temporally connected to their gift is among the most distinctive elements of the branching time analysis and it bears some attention. On Lewis' account, the things playing the counterpart-role (worlds and their parts) are utterly disconnected from targets. There are many possibilities for this world, but the things Lewis postulates to ground these possibilities are utterly disconnected from this world. No matter how far you travelled in space and time, you'd never find one.

By contrast, on the branching analysis, what is possible (given the present moment, for example) is grounded in the past or future of the present moment. Perhaps The World has utterly disconnected parts, but the branching analysis grounds possibilities without postulating utter disconnection. After all, counterparts have a sort of link via their temporal connection to their shared gift. They are weakly temporally connected. Thus, while the branching analysis does not require that every part of The World be weakly temporally connected, it is consistent with the claim that everything that exists is weakly temporally connected with everything else - or else simultaneous.

In this way, the branching time analysis has an actualist-ish appeal. Suppose that the actual world exhausts the whole of reality. Next, accept a detaching reductionism, according to which alternative possibilities are grounded in counterparts. Finally, adopt the Lewisian thesis that something is part of a world only if it is somehow connected spatio-temporally to the parts of that world (Lewis 1986). Then: only things that are somehow connected spatio-temporally (perhaps by being weakly temporally connected) are available to be counterparts. On this line of thought, connection is required for possibility because only connected things exist. The possibilities entailed by temporal indeterminism require a branching analysis insofar as they require analysis in terms of actually existing things.

But even if actualism is false, we might smile on the thesis that counterparts are weakly temporally connected.[25] Suppose that there are non-actual things. Even so, it might be held that what is really possible at a world (or its bits) must be grounded in that world (or its bits). Then: within-a-world connection is required for possibility because only things that are so connected could be such as to ground those things that are possibilities at that world (or its bits). What is hereabouts possible requires a branching analysis insofar as it requires analysis in terms of things that exist hereabouts.

3.1: The Branching Space Analysis

The branching time analysis postulates counterparts and a distinctive pattern of temporal (dis)connection to account for possibilities. On the branching time analysis: for each {*t* and *g*} such that t is a target of alternative possibilities given *g*, there is a counterpart *c* such that (i) *c* differs

[25] Indeed, Belnap and his coauthors appear prepared to accept the existence of other worlds – though they also deploy scare quotes, suggesting serious doubts (Belnap et al. 2001: 188). They insist only that such things could not ground what they call "real possibilities".

intrinsically from *t*, (ii) *c* is not strongly temporally connected to *t*, and (iii) *c* and *t* are sufficiently similarly situated with respect to *g* – entailing that *t* and *c* are each strongly temporally connected to *g*.

A branching space analysis sticks to this scheme as much as possible. It postulates the existence of counterparts, requiring that they be appropriately spatially (dis)connected to each other and to their gifts. We have two initial tasks: specifying the nature of these counterparts and specifying the relations among them that the branching space analysis deploys.

The possibilities entailed by spatial indeterminism concern things that are spatially separated but not temporally separated. Thus, in the case of the branching spatial analysis, we have to invoke targets, gifts, and counterparts that are not moments. But this need introduce no confusion. The parts of moments are the same sorts of things as moments themselves. Indeed any part of a moment can be coherently conceived to be a moment – if its fellow moment-parts were absent.

Whereas the branching time analysis postulated a relation between temporal points - i.e. moments – a branching space analysis is best formulated in a way that might apply to either point-like or non-point-like objects. Unlike the temporal case, for the branching space analysis, I postulate a relation among variably spatially extended parts - a relation that can exist between point-like as well as non-point-like objects.[26]

Because of this, our relation will be defined relative to a partition of a moment. A **partition** can be defined as follows:

For any *x*, a class *P* is a partition of *x* if and only if:

(i) *P* is exclusive: for each *e* such that *e* is an element of *P*, *e* is a part of *x*;

&

[26] If it should turn out that a partition of the The World into temporally un-extended moments is not right and good, a branching space analysis that allows for flexibility with respect to the granularity of a partition will point the way for a better branching time metaphysic.

(ii) P is mereological discrete: for each e such that e is an element of P, e is mereologically disjoint from any other element of P: nothing is both part of one element of P and part of another element of P;

&

(iii) P is exhaustive: for each y such that y is part of x, then either y is an element of P or there is an element of P such that y is part of it; or else y is a fusion only of either elements of P or parts of elements of P;

&

(iv) P has more than one element.

For example, imagine a cube of with a volume of 1000 units. One partition of the moment would contain 8 cubes with volumes of 125 units. Each element in this partition of the cube would be a cube with a volume of 125 units. Another partition of the cube would contain 64 cubes with volumes of 15.625 units. Each element in this second partition would be a cube with a volume of 15.625 units.[27] Our *relata* are going to be elements of partitions of moments. Call these **regions**.

Now for our relation. Consider the relation between two things that are exactly 10 feet apart. This relation is partly composed of a relation of **strong spatial connection**. Strong spatial connection is our primitive relation and I will give it only a functional description. Their connection has a determinate measure (its particular length), because they are strongly spatially connected. Strong spatial connection is also a prerequisite of their being parts of the same space. Moreover, it is a prerequisite of one thing being between two things that they are all mutually strongly spatially connected. It is a prerequisite of one thing being adjacent to another that they are strongly spatially connected. Etc.[28]

[27] Partitions need not be regular in the way these are.

[28] In the case of the branching time analysis, the analogous relation (strong temporal connection) was defined in terms of temporal priority. Here, I treat strong spatial connection as a primitive. I address the possibility of further analysis of strong spatial connection in terms of priority relations below.

Spatial indeterminism is true if and only if there are any spatially indeterministic moments. A moment is spatially indeterministic if and only if it has a spatially indeterministic partition. A partition P of a moment is **spatially indeterministic** if and only if:

> There are at least two elements $\{e_1$ and $e_2\}$ of partition P and states $\{S_1$ and $S_2\}$ such that: (i) e_1 is S_1 and e_2 is S_2 and (ii) e_1 and e_2 are strongly spatially connected and (iii) it is possible (given that e_1 is S_1) that e_2 not be S_2.

Thus, if spatial indeterminism is true, there is at least one region such that there are alternative possibilities (given another region) for it.

Consider two regions r_1 and r_2 such that r_2 is a target of alternative possibilities (given r_1). On the branching space analysis, possibilities are to receive a detaching reductive analysis. The possibility (given r_1) that r_2 be as it is, is grounded in r_2 – i.e. in r_2 being the way it is. The possibility (given r_1) that r_2 differ is grounded in a counterpart differing intrinsically from r_2, but not differing in its spatial relation to r_1.

Spatial Counterparts

For any $\{c, t,$ and $g\}$ such that t is a target of g:

c is a counterpart of t

if and only if

(i) c differs intrinsically from t;

&

(ii) c and t are not strongly spatially connected;

&

(iii) *c* and *t* are exactly similarly strongly spatially connected to *g*.

Note the immediate consequence: Clauses ii and iii entail that if the branching space analysis is true, The World has a branching spatial structure.[29] Moreover, we would ordinarily assume that spatial connection is transitive, but this cannot be assumed, if there might be spatial branching. Let 'Cαβ' express the relation two things have just in case one is strongly spatially connected to the other. Spatial connection is transitive if and only if: for any three regions $\{r_1, r_2, r_3\}$ such that Cr_1r_2 and Cr_1r_3: Cr_2r_3. But, if The World has a branching spatial structure then this is not so - since counterparts are not strongly spatially connected.

These clauses play the same role in the branching space analysis as the analogous clauses in the branching time analysis. Clause i provides a detaching reductionism. Clause ii provides for the coherence of The World. Clause iii requires that counterparts be similarly spatially connected to their gift and so shares the actualist-ish virtues of the iii-clauses of the branching time analysis.

As with the branching time analysis, we must postulate the existence of extended instances of coherence. It had better not be the case that a sea-battle and a pacific cruise are competing for the same space *over there*. The spatial analog to a history would be what I'll call a **leaf**. A leaf is a whole composed all and only of elements of a partition of a moment that are mutually strongly spatially connected. They are necessarily non-branching. It is relative to a leaf that things possess those properties depending on spatial extent. For example, in a branching space, composite objects possess mass only relative to a leaf. And, relative to one leaf, there is a sea-battle over there and, relative to another, there is not.

[29] While the truth of temporal indeterminism is something of an open question, I am aware of nobody who disputes the truth of spatial indeterminism. Thus, the truth of the branching space analysis would appear to suffice for the startling conclusion that The World has a branching spatial structure.

3.2: The Branching Space Analysis: Further Analysis?

Notice that, so far, the branching space analysis is somewhat schematic. What I mean is: in the case of the branching time analysis, the relevant sort of connection and the relevant similarity among counterparts both receive an account. By contrast, I do not provide an account of strong spatial connection, nor do I provide an account of the way in which spatial counterparts are similarly situated. I think it is not necessary to give an account. Given my polemical goals, the relevant relations can remain undefined - though the precise commitments taken on by an advocate of the branching space analysis will remain somewhat underdetermined in the absence of further analysis.

However, I can partly nail down the relevant concepts by articulating some of their functional features. I have already given some functional analysis of strong spatial connection. Let me say a little about the way in which spatial counterparts are similarly situated.

Exact similarity between counterparts' spatial connection to their shared gift comes down to these sorts of facts: If there is some determinate distance between a gift and a target, the very same determinate distance exists between the target's counterpart and the gift. If the target has an address in an n-dimensional coordinate system, the counterpart also has that address. If the target lies in a particular direction away from the gift, so does the counterpart. etc.

Further progress depends on revisiting the notion of spatial connection. In the case of the branching time analysis, the analogous relation (strong temporal connection) was defined in terms of temporal priority. Two things are strongly temporally connected if and only if one is temporally prior to the other. Thus strong temporal connection is defined by reference to things' position in a temporally ordered sequence. Exact similarity of situatedness for temporal counterparts is then understood in terms of positions in a temporal order.

Luckily, there is such a thing as spatial order. Thus it should be possible to provide further analysis of strong spatial connection in terms of something analogous to temporal priority relations. Imagine that you travel from St. Louis to Chicago along Interstate 55. A bit after leaving St. Louis, you arrive in Springfield. Eventually, you arrive in Chicago. Your motion unfolded in time, but the temporal order of your arrival at the various locations along Interstate 55 reflects a pre-existing spatial order. The temporal order of your arrivals is determined by the spatial order of things along a pathway bounded by Chicago and St. Louis. It is arbitrary whether we represent the order in a St. Louis-to-Chicago direction of travel or whether we represent that order in a Chicago-to-St. Louis direction of travel. Then we can define spatially connected regions as follows: regions are spatially connected if and only if one is spatially prior to the other.

But the payoff really comes for understanding similarity of spatial situatedness. In the branching time analysis, counterparts are exactly similarly situated insofar as the pathway through time that connects them to their shared gift is the same. Similarly, in the branching space analysis, we would require that spatial counterparts be exactly similarly spatially situated with respect to their shared gift if and only if the pathways that connect them are the same.

4: Conclusion

The warrant for treating the two analyses as a package rests on the analogies between them: in both cases we find similar modal relations (i.e. necessitation given a gift), obtaining among *relata* that are also similarly related non-modally (i.e. via connection, spatial or temporal), among similar *relata* (i.e. moment-like things).

Insofar as the resulting analyses are structural analogs they share theoretical virtues. If detaching reductionism is a virtue, then it is a virtue of both accounts. If counterparts need to be

disconnected from each other but connected to their shared gift, then both analyses are attractive insofar as they satisfy this need. If counterparts need to be exactly similarly situated with respect to their gift, then both analyses are attractive insofar as they satisfy this need. (Relatedly, part of the warrant for extending a branching analysis to the spatial case rests on the apparent coherence of doing so. Coherent accounts of modality are thin on the ground and to be treasured wherever they are found.)

Of course, recall the point I made earlier: there are differences between space and time, and so it is not guaranteed that the branching time analysis succeeds only if the branching space analysis does. But if you would resist the claim that the two are a package you would do well to identify some difference between temporal connectedness and spatial connectedness that would (i) warrant providing a branching analysis of one and block providing a branching analysis to the other and also (ii) block adapting the non-branching analysis from one to the other.[30]

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