Conventionalism about time direction

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Abstract

In what sense is the direction of time a matter of convention? In *The Direction of Time*, Hans Reichenbach makes brief reference to parallels between his views about the status of time's direction and his conventionalism about geometry. In this article, I: (1) provide a conventionalist account of time direction motivated by a number of Reichenbach's claims in the book; (2) show how forwards and backwards time can give equivalent descriptions of the world despite the former being the 'natural' direction of time; and (3) argue that this offers an important middle-ground position between existing realist and antirealist accounts of the direction of time.

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1   Introduction: When time does and does not have a direction

> [I]f someone argues that it is a matter of convention to select the
> direction of growing entropy as the direction of time, [...] they must not
> commit the error [...] of overlooking the empirical content associated
> with the use of this convention.   (*Reichenbach*, *1956*, *p. 154*)

Although conventionalist attitudes towards spacetime geometry,[1] temporal duration[2] and simultaneity[3] are well known,[4] little has been written about what it means to be a conventionalist with respect to the *direction* of time. Nonetheless, this appears to be a position adopted by Hans Reichenbach in his book *The Direction of Time* (hereafter DoT). In this article, I provide a conventionalist account of time direction motivated by Reichenbach's views, place it in relation to his more well-studied geometrical conventionalism, and explore the relationship between time-direction conventionalism and related accounts of time direction.

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[1]E.g. Poincaré (1905); Reichenbach (1957).

[2]E.g. Poincaré (1976).

[3]E.g. Reichenbach (1957), Poincaré (1976).

[4]See Ben-Menahem (2006) and Friedman (1983, ch. 7) for classic discussions of conventionalist positions in philosophy of physics.

As the title of the book suggests, DoT provides an account of time direction. However, Reichenbach holds that there is also a clear sense in which time does not have a direction: it is equally true to describe the world as directed from future to past as it is to describe it as directed from past to future. Instead, Reichenbach holds that it is more convenient to use past-to-future talk, and that the convention of describing the world from past to future has an empirical grounding. Though his remarks point to a conventionalist thesis of time direction, in line with his geometric conventionalism, the position is only discussed in fragments within DoT, and has not been set out in the secondary literature. However, conventionalism about time direction is a coherent and promising account of the epistemology of time direction, and has parallels with, but important divergences from, modern antirealist accounts of the direction of time. In particular, I argue that Reichenbachian conventionalism about time direction offers a plausible new angle on the explanatory specialness of the low-entropy early universe.

Reichenbach presents us with a seeming contradiction: forwards and backwards time are equivalent in that they describe the same world; but the direction of increasing entropy, and not the direction of decreasing entropy, should be regarded as the positive direction of time for 'empirical' reasons. In order to make sense of Reichenbach's position, and to articulate a general conventionalist account of time direction, the paper is structured as follows. Section 2 sets out the view that forwards and backwards time give 'equivalent descriptions' of states of affairs, how Reichenbach motivates this view in the context of time-reversible systems, how it also applies to time-asymmetric processes in the world, and how this relates to the question of whether time is directed. Section 3 relates Reichenbach's remarks about the conventional nature of the direction of time to his wider conventionalism, particularly his theory of equivalent descriptions in the context of geometry. Section 4 sets out the entailments of a conventionalist thesis about time direction and considers the empirical grounding of the convention of taking growing entropy, as opposed to decreasing entropy, to be the positive direction of time, and how this relates to humans' preference for causal rather than teleological explanations. In section 5 I argue that conventionalism about time direction offers a best-of-both-worlds option between existing realist and antirealist accounts of time direction, and show how it offers a novel perspective on the re-

lationship between the directionality of time and the explanatory status of the low-entropy early universe. Section 6 is the conclusion.

2   The equivalence of forwards and backwards time

2.1   Equivalence and time symmetry

In the context of a discussion of the lack of irreversible processes in classical mechanics, Reichenbach remarks that '[s]ince it is always possible to construct a converse description [of a process], positive and negative time supply *equivalent descriptions*, and it would be meaningless to ask which of the two descriptions is true' (Reichenbach, 1956, pp. 31-32; my emphasis). Reichenbach takes it that all processes allowed by classical mechanics are reversible, meaning that for any two kinematically possible states x and y, if it is possible for a system to transition from x to y (i.e. in our 'future' direction), then it is also possible for a system to transition from y^* to x^*, where '$*$' denotes the time reversal operator.[5] As such, Reichenbach takes it to be superfluous to describe any process in a particular direction of time. For instance, if we consider a perfectly elastic collision of two billiard balls of equal mass, where (for instance) there is a total transfer of momentum m from one ball (Ball 1) to the other (Ball 2), there is no sense in which the momentum is 'really' transferred *from* one ball *to* the other, since in one direction of time the transfer is from Ball 1 to Ball 2, and in the other the transfer is from Ball 2 to Ball 1. Since both descriptions are 'equivalent', and it is 'meaningless to ask which [...] is true', we can regard them to equivalently express the same time-order facts, namely that the collision occurs temporally between Ball 1 having zero momentum and Ball 2 momentum m, and Ball 1 having momentum m and Ball 2 having zero momentum.[6]

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[5]Though ideally one might like to think of time reversal invariance as holding that a theory allows some sequence of states if and only if it also allows the temporally reversed sequence *of the same states*, in reality time reversal also has to operate on the so-called 'instantaneous' states of systems. For instance, if we define a state of a Hamiltonian system in terms of the position and momentum of a single particle, the time reverse would be the same position but the opposite momentum (as though the particle were headed in the opposite spatial direction).

[6]In this case the two time-directed descriptions would differ as to the values of the momenta of the balls, since each description would ascribe the negative momentum of the other, so here 'm' refers to an adirectional surrogate of momentum.

2.2   Equivalence and time asymmetry

Although Reichenbach motivates his claim of forwards and backwards time being equivalent in the context of classical mechanics, with the absence of irreversible processes, it is clear from later remarks in DoT that he takes this equivalence to hold even with respect to irreversible macroscopic processes, where a direction of time is definable. This is most notable in his discussion of the time asymmetry of entropy. Reichenbach, building on Boltzmann's view that the difference between past and future can be grounded in terms of the entropy gradient, provides a definition of the direction of time as 'the direction in which most thermodynamical processes in isolated systems occur' (ibid., p. 127). However, he adds that due to the equivalence of time-directed descriptions 'it has no meaning to say [...] that [...] entropy "really" goes up, or that its time direction is "really" positive' (ibid., pp. 128–9), later noting that

> The two languages L_1 [a language in which the positive direction
> of time is that of increasing entropy] and L_2 [a language in which
> the positive direction of time is that of decreasing entropy] represent
> *equivalent descriptions*; one is as true as the other. (Reichenbach, 1956,
> p. 154; emphasis in original)

This shows that the equivalence of forwards and backwards time is not merely a property of ideal time symmetric or reversible systems, but applies also to time asymmetric systems such as the macroscopic world. But here lies a problem: there are clear senses in which forwards and backwards time give descriptions of the world that are inequivalent in numerous ways. This kind of view has been taken by Gold (1966, p. 327; emphasis added), who notes that 'the description of our universe in the opposite sense of time [...] *sounds very strange* but it has no conflict with any laws of physics. [The] strange description is not describing another universe, or how it might be but isn't, but it is describing the very same thing'. Similarly, Price (2004, p. 231; emphasis added) holds that since there is 'no objective sense in which what we call the future is really the 'positive' direction of time, then we can equally well describe the world by reversing the usual temporal labelling[, ...in which] the familiar expansion from a smooth big bang

becomes a contraction to a smooth big crunch, with […] *extraordinary characteristics*'. Clearly a backwards-in-time description of everyday processes yields apparent bizarre and improbable behaviour, such as anti-thermodynamic processes. A key part of Reichenbach's conventionalism is to make sense of how and why our ordinary past-to-future direction of time is to be preferred over its converse. Before turning to Reichenbach's wider conventionalist thesis to make sense of this, we can first isolate the exact problem with which conventionalism about time direction is concerned.

2.3　Asymmetry and directionality: what's at stake?

It is important to isolate the central point at issue in Reichenbach's time direction conventionalism, and separate it from other features he attaches to the directionality of time. The question is: once we have fixed some definition for distinguishing two temporal directions (for example the direction of 'increasing entropy' of systems and the converse direction of 'decreasing entropy') what is the relative status of these two directions? Is one the 'normal' or 'natural' direction, or is the choice between them a more arbitrary matter? This issue is independent of how the two directions are distinguished. Reichenbach's account of time direction in DoT depends largely on his 'branch systems' hypothesis.[7] But conventionalism about time direction does not stand or fall with the branch systems hypothesis. More abstractly, we can imagine some idealised asymmetry holding locally between the two directions of time, such that we're able to distinguish them. The question of conventionalism is: on what grounds do we consider one of these the 'positive' direction of time?

　　This issue is also independent of the local nature of time direction in Reichenbach's account. Reichenbach builds on Boltzmann's suggestion to define 'earlier' and 'later' roughly in terms of the local entropy gradient,[8] leaving open, like Boltz-

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[7]Reichenbach considers *branch systems* — quasi-isolated systems which 'branch off from a comprehensive system and remain isolated from then on for some length of time' (Reichenbach, 1956, p. 118). His *branch systems hypothesis* holds that (1) the universe is currently in a relatively low-entropy state, and (2) there are many branch systems within our universe. Given this, he defines positive time as 'the direction in which most thermodynamical processes in isolated systems occur' (ibid., p. 127).

[8]"[T]he two directions of time are indistinguishable, just as in space there is no up and down […....

mann, the possibility that the positive direction of time can vary at different sections of the universe, meaning that there can fail to be a global direction of time whilst still existing local directions of time. This point is criticised by Earman (1974), who argues for the preference of a globalisable definition of positive time. But even if we have a globalisable definition of time direction, such as a temporal orientation on a relativistic spacetime (like Earman suggests), the question of conventionalism reoccurs: what grounds the preference of one set of timelike vectors over the reverse set as the 'positive' direction of time?

So we are able to abstract away from some of the more contentious finer details of Reichenbach's program in DoT to isolate the question of time direction conventionalism. Even though an asymmetry such as thermodynamic irreversibility is sufficient to define a direction of time, the question of whether the direction of increasing entropy or the direction of decreasing entropy should be taken to be the 'positive' direction of time requires a different resolution. This point is not unique to Reichenbach. For instance, Price (2002, p. 88) makes the point that while 'some people may feel that they can make sense of the possibility that [...] there is an objective fact in nature about the slope of [the] entropy gradient — whether it is positive or negative', such a view requires 'a further fact to be explained, in addition to the existence of the gradient itself', conceding that he 'do[es] not understand what that additional fact could be, or what could count as evidence for it, one way or the other'.[9] The key point is that the ability to define a direction of positive time is not alone sufficient to justify the choice of one such definition over its inverse.

J]ust as at a particular place on the earth's surface we call "down" the direction toward the center of the earth, so will a living being in a particular time interval of such a single world distinguish the direction of time toward the less probable state from the opposite direction (the former toward the past, the latter toward the future)" (Boltzmann, 1964, pp. 446–447).

   [9]The philosopher C.D. Broad (1938, pp. 521–2) makes an analogous point in response to McTaggart's (1927) claim that the past-to-future direction is the 'fundamental sense' of time on grounds of circularity. McTaggart takes the movement of the present from earlier to later times to privilege the past-to-future direction, but Broad notes that this simply '*presuppose[s]* that the direction in time from earlier to later is more important than the direction from later to earlier'; if we prefer the later-to-earlier direction, we could alternatively say that time 'passes' in the opposite direction.

3   Conventionalism and equivalent descriptions

Although Reichenbach holds that the past-to-future and future-to-past directions provide equivalent descriptions of the world, there are what he calls 'empirical' grounds for preferring the past-to-future mode of describing processes. This fits with his own specific brand of conventionalism developed in the context of geometry, according to which the choice of one description from a set of equivalent descriptions is not necessarily arbitrary, and in some cases can be preferred on empirical grounds. In this and the following section, I show how his remarks about why we should (and do) prefer a language of increasing entropy fit with his conventionalism about geometry, and offer some suggestions for what this means about the status of the directionality of time.

3.1   Parallels between geometry and time direction

In taking forwards-in-time and backwards-in-time descriptions to be equivalent, Reichenbach (1956, p. 31, fn. 2) makes specific reference to his 'theory of equivalent descriptions', formulated in other works in the context of geometry, specifically to his (1951) book *The Rise of Scientific Philosophy* (RoSP). There, a number of his remarks about the conventional yet empirical status of geometry parallel a number of remarks about time direction in DoT. Though DoT does not explicitly identify or elaborate on these parallels or the specific place of time direction within the theory of equivalent descriptions,[10] his views on geometry are instructive as to how to regard the status of time's directionality.

When discussing Henri Poincaré's conventionalist thesis of geometry in RoSP, Reichenbach remarks:

> Poincaré was right if he wanted to say that the choice of one from the class of equivalent descriptions is a matter of convention. But he was mistaken if he believed that the determination of *natural geometry* […] is a matter of convention. This geometry can only be ascertained empirically. (Reichenbach, 1951, pp. 134–135; emphasis added)

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[10]DoT was published posthumously and incomplete.

Elsewhere in RoSP, Reichenbach notes that it is an 'empirical fact' that 'the *natural geometry* of the world of our environment is Euclidean' (ibid., p. 137; emphasis added). This focus on the non-arbitrary nature of conventions, and the possibility of a convention having empirical support, and so there being a 'natural' description within a set of equivalent descriptions, is also gestured towards in his discussion of time direction in DoT:

> If someone argues that it is a matter of convention to select the direction of growing entropy [as opposed to decreasing entropy] as the direction of time, [their] conception cannot be called false. But [they] must not commit the error often connected with other forms of conventionalism: the error of overlooking the empirical content associated with the use of this convention. (Reichenbach, 1956, p. 154)

There are clear parallels between these passages, indicating that Reichenbach took claims such as 'the geometry of our environment is Euclidean' and 'entropy increases over time' to have similar conventional yet empirical status.[11] Reichenbach at one point also adds the claim that a language of increasing-entropy 'appears to us as a more natural language' (ibid.) than a language of decreasing entropy. Indeed, Reichenbach provides enough detail in DoT, particularly in the passages on pp. 153–6, to make clear in what sense he takes the direction of time to an empirically-grounded convention. In the rest of this section, I show how his account of equivalent descriptions in the case of geometry carries over to his views on time direction.

3.2   Reichenbachian conventionalism

Reichenbach has been interpreted both as a conventionalist about geometry, and as an (non-conventionalist) empiricist about geometry. In his earlier work, he took his views on the status of geometry to diverge from Poincaré's conventionalism in that he rejected the idea that different geometrical frameworks were on an equal standing, though in his later work he indicated that his views were much closer to Poincaré's. Poincaré (1905, p. 50) famously held that, contrary to Kant,

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[11]This passage is the clearest statement of time direction conventionalism within DoT, and I return to in in sec. 4.1.

'[t]he geometrical axioms are [...] neither synthetic a priori intuitions, nor experimental facts[; ...t]hey are conventions,' the idea being that we require the epistemic category of *convention* in addition to the Kantian options of analytic a priori, synthetic a priori and synthetic a posteriori to accommodate geometrical statements;[12] crucially holding not merely that geometrical facts are empirically underdetermined. Rather, Poincaré holds that geometrical axioms are 'only definitions in disguise', with our choice between possible conventions being 'guided by experimental facts' (ibid.). Ultimately, questions about whether a geometry is true 'ha[ve] no meaning. One geometry cannot be more true than another; it can only be more convenient' (ibid.).

Reichenbach's own conventionalist views about geometry share key features with Poincaré's. Reichenbach's conventionalism is characterised by the idea that there are no geometrical facts about the world, but there are various different equivalent geometrical systems that can be used to represent the world, with some being simpler or more natural in light of the empirical facts, and hence preferable. In his earlier writings, Reichenbach rejected the label of conventionalism for his own views about geometry primarily on the ground that something's being a matter of convention implies that it is to some extent arbitrary, something Reichenbach strongly opposed in the case of geometry, noting in his 1922 article 'Der gegenwärtige stand der relativitätsdiskussion' (translated and reprinted as Reichenbach (1958) 'The present state of the discussion on relativity') that 'I should not like to choose this name ['conventionalism'] for my view. [...T]he term 'convention' overemphasizes the arbitrary elements in the principles of knowledge' (Reichenbach, 1958, pp. 38–39). Rather, he holds that for the theory of relativity, the 'choice of geometry [...] is *no longer* arbitrary once congruence has been defined by means of rigid bodies' (ibid., p. 38).

However, in his later writings, Reichenbach uses the notion of 'convention' and 'conventionalism' more widely in discussions of his theory of equivalent descriptions, noting parallels with Poincaré's views, and crediting Moritz Schlick for pointing out his earlier misinterpretation of Poincaré's conventionalism.[13] For in-

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[12]See Ben-Menahem (2006) and Ivanova (2015) for this reading of Poincaré's notion of convention.

[13]Reichenbach (1958, pp. 38–39) remarks that he 'agree[s] with Schlick, who drew my attention

stance, in RoSP, Reichenbach responds to Einstein's (1949) discussion of conventionalism — in which Einstein uses a fictional dialogue between Poincaré and Reichenbach — to deny that his own views are substantially distinct from Poincaré's conventionalism, remarking that '[s]ince I believe that there can be no differences of opinion between mathematical philosophers if only opinions are clearly stated, I wish to state my conception in such a way that it might convince, if not Poincaré, yet Professor Einstein' (Reichenbach, 1951, p. 135), before continuing with an updated presentation of his geometric conventionalism, which we come to below.[14]

3.3   Geometry and equivalent descriptions

Reichenbach's own understanding of non-arbitrary conventions is based on the idea that we can empirically determine the properties of spacetime once we have fixed certain 'coordinative definitions' — those that coordinate physical theory to measurement, such as defining a metre of length in terms of a stick in Paris, or a straight line in terms of the path of a light ray. A core component to Reichenbach's geometric conventionalism is the contention that we cannot establish through observation whether an object retains its size when transported in space, and so the introduction of coordinative definitions as conventions plays a key role in providing empirical meaning to theoretical statements. To illustrate his view, in his book *The Philosophy of Space and Time* (1957) (originally published in German in 1928 as *Philosophie der Raum-Zeit-Lehre*) Reichenbach makes use of the idea of

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to this matter, that Poincaré, the father of conventionalism, would acknowledge the restricted character of the combination of the principles and that his stress on the arbitrariness of the principles themselves was due to the historical context in which he wrote'. See Friedman (1999, pp. 62–64) and Stump (2015, pp. 76–80) for discussions of Schlick's criticisms of Reichenbach's views on conventionalism in his first book *The Theory of Relativity and A Priori Knowledge* (Reichenbach, 1965).

    [14]In order to flesh out the conventionalist aspects of Reichenbach's views about time direction, I am using the parallels between these and his geometric conventionalism. It is worth noting here that both Poincaré and Reichenbach's conventionalism does also concern other issues relating to time, namely the measurement of simultaneity and duration of processes. Poincaré (1976) and Reichenbach (1957) both consider the Einsteinian worry of how it is possible to synchronise two distant clocks, noting that ultimately this depends upon a simultaneity convention: one cannot measure that two distant things happen at the same time for much the same reason that one cannot determine that a measuring stick does not change length upon moving from one object to another; in both cases a coordinative definition is required to determine simultaneity and so also to determine that two processes are of equal duration. These conventionalist aspects of time stem from concerns about measurement, which is not the case for the conventionalist thesis about time direction.

a universal force — one that has some particular effect on a body regardless of its composition, e.g. one that could shrink a wooden stick and a metal stick by an equal factor. When transporting a measuring rod from one object to another object in space, in order to check whether the objects are of equal length, it is a standard presupposition that there is no such force and so that the rod does not itself change in size while being transported. Only once this presupposition is fixed as a coordinative definition can we take our measurements to determine whether or not the objects are indeed of equal length, and so determine metrical relations between bodies:

> There is no way of knowing whether a measuring rod retains its length when it is transported to another place; a statement of this kind can only be introduced by a definition. (Reichenbach, 1957, p. 16)

Since such a universal force would be empirically undetectable and invalidate our measurements, it is convenient, Reichenbach suggests, to disregard the existence of such a thing, even though this is not empirically forced.

Reichenbach considers a universal force F that distorts measuring instruments 'in such a way that the actual geometry is an arbitrary geometry G, while the observed deviation from G is due to a universal deformation of the measuring instruments' due to F (ibid., p. 33). A consequence of this is that it establishes, according to Reichenbach, the equivalence of all geometries — 'it follows that it is meaningless to speak about one geometry as the *true* geometry' (ibid.). Instead, he holds that only the combination of $G+F$ is a 'testable' statement. Reichenbach builds on this in later writings, developing his theory of equivalent descriptions:

> This consideration shows that there is not just one geometrical de-scription of the physical world, but that there exists a class of equiv-alent descriptions; each of these descriptions is true, and apparent differences between them concern, not their content, but only the languages in which they are formulated. (Reichenbach, 1951, p. 133)

Reichenbach asks us to assume that the following two descriptions were com-patible with empirical observations of the world:

Class G1:

> **G1a**. Euclidean geometry + universal force
>
> **G1b**. Non-Euclidean geometry + no universal forces

And that the following two descriptions were compatible with a different possible world, distinct from the actual world:[15]

Class G2:

> **G2a**. Euclidean geometry + no universal forces
>
> **G2b**. Non-Euclidean geometry + universal force

The members within an individual class are equivalent descriptions; Reichenbach holds that each such description is of equal truth value, and it would be 'erroneous' to discriminate between them. It is this equivalence of descriptions *within a class* that he identifies with conventionalism:

> Conventionalism sees only the equivalence of descriptions within one class, but stops short of recognizing the differences between the classes. (Ibid., p. 136)

The different classes of descriptions are not equivalent. Reichenbach takes it to be an empirical matter as to which class is true: 'the different classes [of equivalent descriptions] are not of equal truth value. Only one class can be true for a given kind of world; which class it is, only empirical observation can tell' (ibid., pp. 136–137). Rather, the two classes are designed to describe different worlds (or different environments within a single world); crucially the two classes should

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[15]In this context, a 'different possible world' is simply meant to correspond to a situation where we have a distinct reality rather than merely a different description of the same reality. Reichenbach is primarily concerned with cases where there *can* be an empirical distinction and where there *cannot*. Equivalent descriptions cannot be empirically distinguished since they are compatible with all the same observations — they can only be pulled apart through the adoption of some specific co-ordinative definition, which is conventional and not empirical (such as ruling out universal forces). Inequivalent descriptions — those that belong to different classes — can in principle be empirically distinguished since they make different empirical predictions, and so they cannot be true of the same world. As such, different classes of descriptions describe different possible worlds.

be empirically distinct, though the empirical data alone could not distinguish between descriptions within a class.[16] Reichenbach is clear that by 'equivalent descriptions' he means that the different members within a single class do not refer to different ways reality could be, but merely different ways of representing a single reality. As such, conventionalism applies in the domain of selecting a single member within a class with which to describe the world. Conversely, the choice between classes is something that can in principle be empirically determined. In order to settle on a description within a class, one must fix a particular coordinative definition, such as ruling out universal forces.

3.4   'Natural' geometry

One aspect of Reichenbach's geometric conventionalism that is of particular importance to the case of time direction is that there can be a 'normal system' or 'natural' description *within* a class of equivalent descriptions, much like how we ubiquitously prefer past-to-future descriptions of processes in the world over future-to-past descriptions.

> Instead of using classes of descriptions, it is convenient to single out, in each class, one description as the *normal system* and use it as a representative of the whole class. In this sense, we can select the description for which universal forces vanish as the normal system, calling it the *natural geometry*. (Reichenbach, 1951, p. 137; emphasis added)

So we have the idea that even in a class of equivalent descriptions one can be considered the 'normal' or 'natural' member. He adds furthermore that we 'cannot even prove that there must be a normal system; that in our world there is one, and only one, must be regarded as an empirical fact' (ibid., p. 137). In the case of geometry, Reichenbach takes Carl Friedrich Gauss' famous experiment — in which he purportedly demonstrated the Euclidean nature of space by means

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[16]To be clear: for Reichenbach two sets of *descriptions* are equivalent if they are different ways of describing the same reality, such as you describing a road from right-to-left and me describing it from left-to-right; and a *class* of equivalent descriptions is a set of descriptions that describe the same reality. For Reichenbach, the empirical data picks out a particular *class* of equivalent descriptions over other classes, but does not distinguish one description within a class.

of constructing a triangle between three mountain tops — to provide empirical evidence for G2a.[17] According to Reichenbach:

> Gauss' experiment presents important empirical evidence. The natural geometry of the space of our environment, within the exactness accessible to us, is Euclidean[....] If Gauss' experiment had [...] revealed a measurable deviation from Euclidean relations, the natural geometry of our terrestrial environment would be different. In order to carry through a Euclidean geometry we then would have had to resort to the assumption of universal forces that distort light rays and transported bodies in a particular way. That the natural geometry of the world of our environment is Euclidean must be regarded as a fortunate empirical fact. (Reichenbach, 1951, p. 137)

This makes clear that Reichenbach considers the convention of *assuming* universal forces to make the data fit a Euclidean geometry to be in some sense unnatural. As Ben-Menahem (2006) notes, Reichenbach's notion of convention is 'that which guides decisions between equivalent descriptions', where such decisions 'are not about truth, but rather, about the best way of representing truth' (p. 116). The implication is that the only relevant fact is that some *class* of equivalent descriptions is true, and there is no deeper fact about *which* of these is true.[18] So what we are considering here is not what *is* the actual geometry of the world, but what is the most convenient description within the empirically preferred class of equivalent descriptions for representing the phenomena. In this case, Reichenbach is implying that the convention of assuming no universal forces is more natural and hence preferable, and as such, given the data, we should prefer G2a and take the geometry of our environment to be Euclidean and not non-Euclidean.[19]

Given his treatment of the past-to-future and future-to-past directions of time

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[17]This is a slightly awkward aspect of Reichenbach's presentation within RoSP, since he previously asks us to assume that the empirical data accords to Class 1 rather than Class 2.

[18]Indeed, Reichenbach notes that 'material objects do not define a single geometry, but a class of geometries; this is precisely the meaning of conventionalism' (Reichenbach 1921; translated by Giovanelli 2013, p. 3840).

[19]The grounds on which the absence of universal forces is 'more natural' is not clear: his words imply that the absence of universal forces is simpler, and that the invocation of an unobservable force would be inelegant.

as providing equivalent descriptions, it is clear that Reichenbach has in mind an analogous conventionalism about time direction, according to which there is no fact of the matter as to the direction of time. But in order to flesh out this position, more needs to be established: what exactly comprises the relevant set of equivalent descriptions we are to choose between; and is there a 'natural' convention that guides us to representing the world as past-to-future directed?

4   What's conventional about time direction?

We're now in a position to ascertain in what sense forwards and backwards time provide equivalent descriptions. As in the case of geometry, it is not simply the case that past-to-future and future-to-past languages will automatically give equivalent descriptions of the world. Rather, equivalence will only apply within a class of descriptions that, together with other coordinative definitions, suffice to make the different descriptions empirically equivalent. The key coordinative principles in the case of time direction turn out to be what Reichenbach calls the choice between whether to represent the world via a principle of 'causality' or a principle of 'finality'.

4.1   Causality and finality

By 'causality', Reichenbach is referring to cases where correlations between variables is explainable in terms of their temporal past; and by 'finality', Reichenbach is referring to cases where such correlations are explainable in terms of their temporal future. In other words, by 'finality' Reichenbach is referring to teleological modes of explanation, where some phenomenon or process is explained in terms of some end goal or 'telos'. However, as Reichenbach uses the terms, causality and finality share the same basic structure, differing only in terms of facts about the direction of time; he suggests that we can only use a language of causality or finality if we have also fixed a direction of time, i.e. either a language of *increasing* or *decreasing* entropy. Elsewhere in DoT Reichenbach uses 'cause' and 'effect' in a time-direction-neutral language, defining them in terms of thermodynamical features of systems: '[t]he cause is the interaction at the lower end of the branch

run through by an isolated system which displays order; and the state of order is the effect' (Reichenbach, 1956, p. 151). In this sense, we can think of the 'cause' as playing the *explanans* role in an explanation and the 'effect' as playing the *explanandum* role.[20] As such, causal explanations are those in which the explanans is earlier in time than the explanandum, and final or teleological explanations are those in which the explanans is later in time than the explanandum.[21]

Reichenbach's discussion of this issue occurs within the context of his presentation of the time asymmetry of records. Were we to describe the process of making a footprint in the sand in reverse time, we would simply explain the existence of the footprint in terms of the 'future' interaction of the surface of the sand with a foot — we would 'explain improbable coincidences [e.g. the jumping of grains of sand into the hollow under the foot so as to leave a smooth surface of sand 'after' the interaction] by their *purpose* rather than by their *cause*' (ibid., p. 153). In other words, in the future-to-past direction, we simply switch causal explanations (i.e. those in which the explanans is in the temporal past of the explanandum) for teleological or 'final' explanations — 'explanation leads to *finality* instead of *causality*' (ibid.). But crucially, Reichenbach takes the two language to be equivalent in the sense that neither is more true than the other:

> Which is the correct language, that of causality or that of finality? This is certainly a meaningless question. The two languages […] represent *equivalent descriptions*; one as true as the other. (Ibid., p. 154)

What we can infer from his discussion of this issue, together with his wider thesis of defining the direction of time in terms of the direction of entropy increase for the majority of branch systems, is a conventionalism about time direction analogous to his conventionalism about geometry. In this case, what constitutes the equivalent descriptions is not merely the converse sets of time-directed descriptions, but a particular combination of (1) a direction of entropy increase or

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[20]Where the 'explanans' is the thing doing the explaining and the 'explanandum' is the thing being explained.

[21]For example, if we consider a case in which the throwing of a stone was the cause of the window breaking, then in reverse time — from future to past — the explanation is teleological since the effect (the breaking of the glass) temporally precedes the cause (the stone throw).

decrease and (2) a language of causality or finality. Fitting this with the structure of Reichenbach's geometrical conventionalism, we can set out the classes of equivalent descriptions in the case of time direction as follows:

Class T1:

> **T1a.** Increasing entropy + causality
>
> **T1b.** Decreasing entropy + finality

Class T2:

> **T2a.** Increasing entropy + finality
>
> **T2b.** Decreasing entropy + causality

As with the case of geometry, descriptions within a class have the same truth value, but the different classes are empirically distinct. This way of presenting time direction conventionalism fits with the following passage in DoT:

> If someone argues that it is a matter of convention to select the direction of growing entropy [as opposed to decreasing entropy] as the direction of time, [their] conception cannot be called false. But [they] must not commit the error often connected with other forms of conventionalism: the error of overlooking the empirical content associated with the use of this convention. (Ibid., p. 154)

It is clear that Reichenbach is drawing parallels between his views on the direction of time and the status of geometry. Reichenbach appears to have multiple 'empirical facts' in mind. One to which he explicitly refers is the 'parallelism of entropy increase' for branch systems: for quasi-isolated subsystems of the universe, as well as the universe itself, the directions of increasing entropy are parallel — they increase in entropy *in the same direction* and not in different directions.[22] It is this that allows us to talk of a general positive time direction being defined, and which

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[22]Reichenbach's principle of parallelism of entropy increase: 'In the vast majority of branch systems, the directions toward higher entropy are parallel to one another and to that of the main system' (Reichenbach, 1956, p. 136). Of course, it follows that the directions towards lower entropy are also parallel.

Reichenbach takes to be an 'empirical hypothes[is] which [is] convincingly veri-fied' (ibid., p. 154). This alone does not pick out the direction of entropy-increase or entropy-decrease, since the parallelism itself is not in any sense directed. But Reichenbach ties this parallelism to the notion of causality, noting that 'the con-vention of defining positive time through growing entropy is inseparable from accepting causality as the general method of explanation' (ibid.), and further:

> Once the direction is assumed in the usual sense [i.e. positive time is the direction of increasing entropy], it is not a matter of personal pref-erence, not a mode of consideration, whether we should describe the world in terms of causes or of ends: *it is a physical law* that causality, and not finality, governs the universe. (Ibid.; emphasis added)

This can be understood in terms of the asymmetric structure of causal networks, in which correlations between variables that are not the direct cause or effect of each other are explainable in terms of their causal past and not their causal future. Reichenbach discusses this in the context of his Principle of Common Cause (Re-ichenbach, 1956, ch. 19), remarking that while some causal forks are closed to the future, such as when two independent events have a common effect, 'a common effect cannot be regarded as an explanation' (ibid., p. 163) of the correlation. This asymmetry is taken by Reichenbach to be due to the second law of thermodynam-ics.

The convention of taking the direction of entropy-increase to be the direc-tion of positive time is tied to the convention of causality over finality: once one is fixed, the other follows empirically. We can regard these as on a par — nei-ther alone is strictly an empirical matter, but once one is chosen, the other is not open to choice.[23] Which of these ought to be the one fixed by convention is not clear from Reichenbach's writings — as we see in the next subsection, he offers justification for each being natural conventions. But regardless of whether we choose causality or finality, or the direction of entropy-increase or entropy-

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[23]This mirrors the dynamical nature of conventions in Reichenbach's wider philosophy; his 'rela-tivised *a priori*' principles. For instance, the light postulate (that the speed of light in a vacuum is a constant $[c = 3.0 \times 10^8 \text{ ms}^{-1}]$) can be taken to be an empirical matter in the context of Newtonian theory, and a coordinative definition (i.e. a constructive principle) in the context of special relativity theory).

decrease, what can be established empirically is that Class T1 is true and Class T2 is false.

4.2   A 'natural' direction of time

Within Class T1, the conventionalist framework allows us a choice between T1a and T1b, but there are overwhelming biological and psychological reasons for preferring each of: causality over finality; and the direction of increasing entropy over the direction of decreasing entropy.

Reichenbach takes the principle of causality and the choice of the direction of entropy-increase as the positive direction of time to go hand-in-hand: 'the convention of defining positive time through growing entropy is inseparable from accepting causality as the general method of explanation' (Reichenbach, 1956, p. 154). But which of these should be regarded as the convention to be fixed, and is there good reason for fixing either over their converse (e.g. a principle of finality, or the definition of entropy-decrease as the positive direction of time)? There appear to be motivations put forward in DoT for each of these to be natural conventions for beings like us.

Ultimately this aspect of Reichenbach's thought is left open due to the incompleteness of DoT, with the final chapter on the connection between physical and psychological time being unwritten at the time of his death. It seems clear however that Reichenbach considered past-to-future time as the 'natural' direction of time, analogous to his conception of a natural geometry within a set of equivalent descriptions:

> That [a language of increasing entropy] appears to us as a more natural language, that we are so strongly disposed toward the identification of the direction from interaction to order with positive time, has its basis in the nature of the human organism. (Ibid.)

Unfortunately this passage continues: 'The discussion of this problem may be postponed' (ibid.), with the added footnote from Maria Reichenbach observing that '[t]his problem would have been discussed in the projected chapter on the human mind, which was to have been the final chapter [of the book]' (ibid., p. 154, fn. 2). Nonetheless, the above passage is interesting as it suggests that the

direction of entropy increase is preferred by humans for biological reasons. Reichenbach elsewhere indicates that he takes us to *experience* time in the direction of increasing rather than decreasing entropy:

> The use of such a language [of finality...] would be extremely inconvenient, because it *contradicts the time direction of psychological experience.* (Ibid., p. 154; emphasis added)

This is a more contentious claim: without a clear account of what 'psychological experience' is taken to be, it is unclear in what sense psychological experience is time directed.[24] If we take psychological experience here to refer to something like the accumulation of memories, then there's a clear sense in which that is directed towards the future (i.e. is parallel to the direction of increasing entropy). In the fragments from the unfinished final chapter of DoT, included in the Appendix, Reichenbach appears to suggest something along these lines:

> Why is the flow of psychological time identical with the direction of increasing entropy? [...] The answer is simple: Man is a part of nature, and his memory is a registering instrument subject to the laws of information theory. The increase of information defines the direction of subjective time. (Ibid., pp. 269–270)

> What we call the time direction, the direction of becoming, is a relation between a registering instrument and its environment; and the statistical isotropy of the universe guarantees that this relation is the same for all such instruments, including human memory. (Ibid., p. 270)

This points to an account where the direction of psychological time is understood in terms of the direction of accumulated memories, which is then underwritten by the asymmetry of records due to the thermodynamic time asymmetry.

It is clear that Reichenbach took T1a to be preferred to T1b, and thus for the direction of positive time to be that of increasing entropy, and for the world to

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[24]See Farr (2022a) for an extended discussion of the question and critique of Reichenbach's remarks about the direction of psychological time.

be governed by causality rather than finality, due to *natural* grounds, namely the nature of human biology and psychology and their connection to the thermo-dynamic time asymmetry. This marks a disanalogy between time direction and geometry, since Reichenbach appears to motivate the choice of a 'natural' geom-etry on the grounds of simplicity — i.e. the elimination of unnecessary universal forces — rather than on the nature of human psychology.[25]

5 The best of both worlds?

With the Reichenbachian conventionalist account of time direction in hand (which I hereafter refer to simply as 'conventionalism'), it is instructive to see how it stands in relation to other accounts of time direction, and what new perspectives it offers to existing debates. First, I show how conventionalism is an antirealist account of time direction[26] that manages to maintain some key motivations of realist accounts, making it a best-of-both-worlds view. And second, I argue that conventionalism helps to clarify an existing problem for antirealist accounts of time direction: the explanatory status of the low-entropy early universe.

5.1 Conventionalism as moderate antirealism about time direction

Realist and antirealist accounts of time direction disagree over whether there is an objective directionality of time. This distinction can be hard to pin down,[27] but we can put it as follows: realism holds that there are time-directed facts that make future-directed descriptions of the world true and past-directed descriptions of the world false; and antirealism denies that there exist such time-directed facts. On this way of demarcating realism and antirealism it is clear that conventionalism is antirealist: truth is attached to classes of equivalent descriptions rather than

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[25]Of course, Reichenbach's conventionalism about geometry has its origins in Kantian epistemol-ogy, and in this sense one can speculate as to whether Reichenbach held analogous views about Euclidean geometry being simpler, more natural, or more convenient for us in part due to facts about our spatial psychology, in line with Kant.

[26]In terminology I defend elsewhere (Farr, 2020), conventionalism is a *C-theory* of time insofar as it holds that there is a key sense in which time is adirectional — crucially there are no time-directed facts according to conventionalism, and so time ultimately lacks a direction in that specific sense.

[27]See Farr (2020) for a discussion of different ways this distinction can be made.

individual descriptions, and descriptions within a class can disagree as to whether the positive direction of time is represented as past-to-future or future-to-past. Hence conventionalism denies there are time-directed facts.[28]

However, conventionalism is a moderate form of antirealism; it shares a feature with realism in that it denies that past-to-future and future-to-past descriptions are wholesale equivalent, making it a middle-ground position. It does this in two ways. Firstly, languages of increasing entropy and decreasing entropy are equivalent only given the right coordinative definitions. As Reichenbach suggests, when using a language of decreasing entropy to describe our world, we are only accurately describing our world if we also adopt a principle of finality; if we instead adopt a principle of causality, implying that lower-entropy states are 'produced' by higher-entropy states, then we are describing a different possible world in the sense that it is empirically inequivalent to the world described by our conventional entropy-increasing causal description. Secondly, conventionalism holds that the entropy-decreasing description of the world obeying a principle of finality is not the natural description of the world, and that the entropy-increasing causal description is preferred. As such, regardless of whether we use forwards or backwards time to describe it, the world accords to a causal structure whereby lower-entropy states explain higher-entropy states and not vice versa. In this way, conventionalism satisfies a key motivation for realist accounts of time direction, namely that there are good grounds for holding that earlier states determine later states of the world and not vice versa.

Because of its hybrid nature, conventionalism offers a kind of antirealism about time direction that avoids a major criticism aimed at antirealist accounts. The time-direction realist Tim Maudlin (2002, 2007, 2012) argues that antirealism about time direction fails to account for why the past-to-future direction provides better explanations of phenomena than the opposite direction, using this to defend his own time-direction realism. Maudlin holds that it is simply a fact that

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[28]A time-direction realist could adopt the epistemically modest position that there *is* a fact as to whether entropy really increases or decreases, but that this fact is underdetermined by experience. This view is importantly different from conventionalism. Instead, conventionalism holds that there simply is no such fact — forwards and backwards time can, together with an accompanying principle of causality or finality, describe the same possible world. The key distinction is that realism holds that forwards and backwards time *do* describe different possible worlds.

'there is [...] a fundamental direction of time, in virtue of which it is correct to say that the universe is expanding and new matter being created, rather than contracting with matter being destroyed' (Maudlin, 2012, p. 166), and that this directionality of time explains why it is that there are probable (i.e. entropy-increasing) evolutions towards the future and improbable (entropy-decreasing) evolutions towards the past: '[t]his sort of explanation requires that there be a fact about which states produce which[, which] is provided by a direction of time' (Maudlin, 2007, p. 134; emphases added), with the implication that an antirealist account of time direction has no such resources. But this characterisation of time-direction antirealism is false since it does not account for conventionalism. Contrary to Maudlin's claim, conventionalism: (a) allows for an objective distinction between causes and effects; (b) denies that the existence of a preferred direction of causal explanation entails that there is a fact about the direction of time; and (c) accounts for why we take the past-to-future direction as the natural direction of time.

As we saw in sec. 2.2, Gold and Price have held a more extreme time-direction antirealism than Reichenbach, suggesting that it is equivalent to say the future produces the past as vice versa, better fitting Maudlin's characterisation of time-direction antirealism. Price suggests that, in the direction of entropy decrease, 'the familiar expansion from a smooth big bang becomes a contraction to a smooth big crunch, with [...] *extraordinary characteristics*' (Price, 2004, p. 231; emphasis added), those extraordinary characteristics being that 'the matter in the universe is collapsing towards a big crunch [...] and that as it does so, something very peculiar is happening [...for example, t]he motions of the individual pieces of matter in the universe are somehow conspiring to defeat gravity's overwhelming tendency to pull things together', etc. (ibid.). Similarly Gold notes that the universe, when described in the future-to-past direction of time, 'sounds very strange', involving processes such as disordered systems tending to become ordered, heat flowing from colder to hotter bodies, dark patches of space emitting radiation, etc. (Gold, 1966, pp. 326–7). In both Price's and Gold's accounts, the equivalence of forwards and backwards descriptions appears to imply the equivalence of descriptions like T1a and T2b, since both authors appear to describe backwards-in-time processes in *causal* rather than *teleological* terms. However, the time-direction conventionalism I have set out holds that when using the direction of decreasing entropy as

positive time, we must be careful to use a language of finality, or else we end up describing a different possible world — one that is not our actual world. This issue becomes particularly pronounced when considering the explanatory status of the low-entropy early universe.

5.2 Conventionalism and the Past Hypothesis

The 'Past Hypothesis' (PH) is the assumption that the early universe was in a macrostate of extremely low entropy, and various philosophers have argued that this is alone sufficient to account for the various arrows of time (e.g. Albert (2000), Kutach (2002, 2013) and Loewer (2007, 2012)). For instance, Boltzmann (1967) holds that the second law of thermodynamics 'can be proved from the mechanical theory if one assumes that the present state of the universe [...] started to evolve from an improbable state and is still in a relatively improbable state', taking the PH to be 'a reasonable assumption to make, since it enables us to explain the facts of experience, and one should not expect to be able to deduce it from anything more fundamental'. The kind of low-entropy macrostate required would constitute an extremely small volume of the phase space[29] of the universe, meaning that if we assign each possible microstate of the universe (i.e. each microstate compatible with the universe's macrostate) equal probability, it is extremely improbable that the universe was ever in such a low-entropy macrostate.[30] Reichenbach's views on this, while motivated by Boltzmann, differ in various ways, and it is unclear how he justifies PH.[31] However, conventionalism offers an interesting counterpoint to two alternative views about how and whether the low-entropy state posited by PH (call this the 'Past State') is to be explained.

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[29]A phase space is an abstract mathematical space in which each point represents a complete kinematically possible microstate of the system in question — i.e. for a classical Hamiltonian picture, the position and momentum values of each particle.

[30]For instance, using Bekenstein-Hawking entropy rather than Boltzmannian entropy, Penrose (1989) calculates that the probability of the universe having been in a state of sufficiently low entropy as 1 in $10^{10^{123}}$.

[31]For instance, he takes Boltzmann's picture to be incomplete, since it does not entail the parallelism of entropy increase (see Reichenbach 1956, p. 137). Reichenbach takes it that for each branch system, there is a 'low-point' of entropy, and that the low-to-high entropy directions are parallel to each other. But there is no specific defence of PH in DoT.

Price (2002, 2004) and Maudlin (2007) share the view that antirealists about the direction of time require a special kind of explanation of the Past State given its improbability.[32] Price holds that if there is 'no objective sense in which what we call the future is really the "positive" direction of time' (Price, 2004, p. 231), then we should take a low-entropy past to be as demanding of explanation as we would a low-entropy future. Described in future-to-past time (i.e. the direction of entropy-decrease) Price holds that the apparent evolution of the universe towards the Past State constitutes an 'extraordinary feat of cooperation' of matter and forces and 'trump[s] anything else ever discovered by physics' (ibid. p. 230). Maudlin, uses analogous reasoning against antirealism and in favour of his own time-direction realism. On the assumption of PH, each microstate of the universe is dynamically atypical insofar as evolution towards the past leads to a lower-entropy macrostate; Maudlin holds that by assuming time has an objective direction — that earlier global states of the universe 'produce' later global states of the universe — this atypicality of microstates is explained away as a product of typical (entropy-increasing) evolution *from* the Past State to the future, with '[t]his sort of explanation requir[ing] that there be a fact about which states produce which[, which] is provided by a direction of time' (Maudlin, 2007, p. 134). Call the problem that Price and Maudlin cite the *Problem of Bad Evolution*:

Problem of Bad Evolution (PBE). If forwards and backwards time are equivalent, then the Past State can be understood as the *product* of vastly improbable evolution from higher-entropy states.

For the reasons laid out in the previous subsection, conventionalism avoids PBE, and as such avoids both Price's conclusion that the Past State requires a special explanation, and Maudlin's conclusion that time direction realism offers an explanatory advantage over antirealism. While conventionalism offers an antirealist account of the direction of time, it takes it to be false that the Past State is the causal product of evolution in the direction of decreasing entropy. On our conventionalist account of time direction, descriptions T1a (increasing entropy and

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[32]The two come apart insofar as Maudlin thinks that a kind of realism about time direction overcomes a key aspect of the problem of PH, whereas Price holds that time direction realism itself offers no solution.

causality) and T2b (decreasing entropy and causality) are not equivalent; rather, Reichenbach takes T2b to be empirically falisified. As such, it is a mistake to think that the equivalence of time-directed descriptions entails that the Past State can be equivalently described as a cause of entropy increase *and a causal product of entropy decreasing systems*. It is only the latter that gives rise to the kinds of vastly improbable conspiracies that Price speaks of, and that Maudlin wishes to avoid. For this reason, conventionalism avoids PBE, and so the antirealist about time direction can deny the future 'produces' the past whilst holding that the past 'produces' the future. Conventionalism holds that forwards and backwards time provide equivalent descriptions of the world only insofar as the former is causal and the latter teleological. In the teleological future-to-past description of the world (i.e. T1b), the Past State functions as part of the explanation of the entropy gradient rather than something *explained by* the entropy gradient.[33]

6   Summing up

Though only discussed briefly within DoT, Reichenbach's views on the direction of time fit a conventionalist thesis of time direction analogous to his conventionalism about geometry. Conventionalism about time direction offers an antirealist account of time direction insofar as it denies that there is an objective fact that time really 'goes' in one direction than the other — in Reichenbachian terms, that entropy really increases or decreases with time. But this equivalence of time directions does not entail that it is equally true to say that the future produces the past as to say the past produces the future. Rather, Reichenbach makes clear that a language of increasing entropy is only equivalent to a language of decreasing entropy if the two languages are in turn accompanied by principles of causality and finality accordingly. Our world is *either*: (1) one governed by causality in which entropy increases; or (2) one governed by finality in which entropy decreases. And (1) is to be preferred over (2) as the 'natural' description of the world for a variety of reasons relating to our human perspective in the world. Understood in this way, conventionalism about time direction offers a useful middle-ground be-

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[33]See Farr (2022b) for an extended defence of time-direction conventionalist reading of the past hypothesis.

tween full-blown antirealism about time direction (in which it is no more true to say that the past determines the future rather than vice versa) and realism about time direction (according to which it is true that entropy increases and false that entropy decreases), offering the antirealist about time direction new options for dealing with problems levelled at antirealist accounts, such as the explanatory status of the low-entropy early universe.

Acknowledgements

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