Journal of Physics:
Conference Series

PAPER • **OPEN ACCESS**

From time to spacetime to no time? The philosophy of relativity theory

To cite this article: Matt Farr 2024 *J. Phys.: Conf. Ser.* **2877** 012078

View the article online for updates and enhancements.

From time to spacetime to no time? The philosophy of relativity theory

Matt Farr

Department of History & Philosophy of Science, University of Cambridge, Free School Lane, Cambridge CB2 3RH, UK
Wolfson College, University of Cambridge, Barton Road, Cambridge CB3 9BB, UK

E-mail: mail@mattfarr.co.uk

Abstract. The shift from classical to relativistic physics significantly altered our conception of time. From a picture of space and time as autonomous concepts, and of reality as divided into moments of time, relativity theory introduced a picture of four-dimensional spacetime, and a 'static' or 'block universe' conception of time. This paper considers how exactly relativity theory clashes with our ordinary folk conception of time and what this ultimately means for how we should think about the nature of time.

1. Introduction

Isaac Newton famously held that '*absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external*'. Newton's notion of universal flowing time certainly had intuitive appeal and to this day is widely regarded by philosophers as fitting with a common-sense picture of time. Since the development of relativity theory, however, an alternative picture of time has come to the fore, one of time as 'static', 'extended' and being represented as the fourth dimension of a spacetime 'block', and it has been popular to regard the resultant picture as sufficiently alien to our concept of time to ultimately regard time as 'unreal' in light of relativity theory. The trouble with all of the terms in scare quotes in the previous sentence is that they are all metaphors, not clearly describing a specific property ascribed to time by relativity theory. It is certainly the case that relativistic physics gives us a different picture of time than non-relativistic classical physics, but to see this one needs to explore the variety of ways that time has come to be understood within both classical and relativistic physics, and what kinds of arguments have been constructed to show how and why the theories of relativity force an update of our conception of time.

1.1. A brief history of (classical and relativistic) time

A central feature of classical physics is the fact that space and time have different metrics. In short, measurements of spatial distances between things are independent of measurements of temporal duration between things. This is encoded in the standard '3+1' spacetime structure used in classical physics, in which spacetime is represented in terms of three-dimensional space and one-dimensional time. Given that these are independent things, one can think of the world as ordered in terms of global 'moments' of time with each moment of time corresponding to an instantaneous three-dimensional space. This idea of space and time is highly intuitive and corresponds to the picture of time as a single 'Now' or 'present moment' that changes by moving upward along the time axis, roughly corresponding to the Newtonian idea of flowing time. However, this intuitive picture of time does not neatly fit with relativistic physics.

The Special Theory of Relativity (first presented in Albert Einstein's famous 1905 paper [1]) sets out a view of time and space as intertwined in the sense that temporal durations and spatial distances are no longer independent things. Rather, when we measure the temporal duration of some process using a clock, we are measuring the time elapsed only relative to a particular frame of reference and different frames of reference can disagree as to the duration between two events (and even as to which event happened first). What is objective in light of Special Relativity is the 'spacetime interval' between two events, which can be determined by putting one's spatial and temporal measurements into a new four-dimensional spacetime metric (the 'Minkowski metric', named after the mathematician Hermann Minkowski). A consequence of this is that key temporal concepts like 'absolute simultaneity' are not preserved in relativistic physics — two distant events may be simultaneous relative to a choice of reference frame, but different reference frames will disagree as to whether those events are simultaneous while having an equal claim to correctness. The way these seemingly incompatible descriptions of the time order of the events can be 'equally correct' is for there to simply be no fact of the matter as to whether the events are 'really' simultaneous, or whether one 'really' happens before the other.

A common view is that relativity theory has shown that traditional ideas of time are wildly mistaken with a range of views being instead defended, such as the idea that time is ultimately 'static', the future 'already real' and one's own future actions 'predetermined'. Many such claims ultimately rest on misconceptions about both relativity theory and our own 'common-sense' ideas of time. This paper addresses these problems and the philosophical arguments that have been put forward, arguing that relativistic time is less counter-intuitive than is often suggested. It will start by looking in more detail at the key philosophical questions about these different pictures of time before looking at the ways in which the theories of relativity answer them.

2. What is common-sense time?

Philosophers of time usually distinguish between two broadly different ideas of time, which can be termed 'dynamic' and 'static'. The dynamic picture of time accords to the idea of time flowing like a river with future things coming into being and then receding into the past, whereas the static picture presents time as an extended dimension akin in various respects to the spatial dimensions with past, present and future events being equally 'out there' in reality.

2.1. Dynamic time

The picture of time as 'dynamic' or 'flowing' can be traced back to pre-Socratic philosophy in the work of Heraclitus of Ephesus, who held that 'everything flows' with reality being in an essential state of 'flux' and with the evocative metaphor of time being like a river, which carries over to Newton's own description of time as intrinsically flowing. In twentieth century philosophy the 'A-theory' of time corresponds to this metaphor. The Cambridge metaphysician J.M.E. McTaggart [2] held that our concept of time accords to what he called the 'A-series', the series of events ordered in terms of being 'past', 'present' and 'future'. For McTaggart the passage of time is the change of events (for example the 2014 FA Cup Final) from being future to being present to finally being past. Although McTaggart himself thought that the A-series was merely an illusion, A-theorists of time hold that time really does pass, that the 'Now' really is a feature of the Universe and that it is constantly moving to later and later times.

Pinning down precisely what the A-theory says about time is, however, not straightforward. There are as many variants of A-theory as there are A-theorists. In the broadest sense A-theories of time hold the following to be the case:

(1) Time 'passes' — it involves a kind of change that is not available to rival 'static' theories of time;

(2) The division of the history of the Universe into 'present' and non-present times is something absolute, objective and independent of our own perspective in time;
(3) Non-present times are divided into past and future times, giving us a direction of time from past to future with the dynamism of time corresponding to the fact that the location of the 'present' time continuously moves from earlier to later times.

There are different ways to accept these claims. The most notable variation between A-theories concerns the difference between present and non-present times. *Presentism* is the view that non-present times simply are not real; past events *did* exist and future events *will* exist, but neither strictly exist. In this sense the Universe is composed only of what is going on *now*, namely all of those things that are simultaneous with what one is doing right now. The *'Growing Block' theory* holds that both present and past things exist; in other words, reality is composed of all those things that have happened or are currently happening. Finally, the *'Moving Spotlight' theory* holds that past, present and future things all exist, but that only one time is ever *privileged*, as though a cosmic spotlight is being shone on one and only one 'present' moment.

As soon as these metaphysical details are added, it is less and less clear why such views constitute 'common-sense' time. However, the standard view is that the ways in which we experience time and talk about time involves reference to the sense of passage and movement of the Now, which A-theories seek to explain in terms of the structure of time itself.

2.2. Static time

Static theories of time deny that time is intrinsically dynamic. To be precise, these theories simply do not seek to define such a property of 'dynamism' or 'flow' to attach to time, instead taking it that the dynamic and flow-like ways in which time is commonly experienced and talked about are compatible with time itself being an extended dimension that can be represented in the same ways in which the dimensions of space are standardly represented.

After introducing the A-series way of talking about time, McTaggart also introduced the B-series and C-series. The B-series orders events in terms of 'earlier' and 'later'. The Battle of Hastings is earlier than the Great Fire of London. Both are earlier than the 2024 General Election. Although people in 1066 did not know about those events that would happen centuries later, the fact that the three events have a particular earlier/later order does not change. In a sense, the Battle of Hastings is 'always' earlier than the Great Fire of London. This is unlike the A-series, where the Battle of Hastings was first *future*, then *present*, then *past*. There is no equivalent change in the B-series — it is fixed in time.

Likewise with the C-series: this series orders events in terms of 'temporal betweenness'. The Great Fire of London is temporally between the Battle of Hastings and the 2024 General Election. It is equivalently temporally between the 2024 General election and the Battle of Hastings. What is key about the C-series is that there is no time direction built into it unlike the earlier/later direction of the B-series. What the B- and C-series have in common is that they do not change as time passes — they are a way of representing what is fixed across time, namely the relative position of events in time [3].

McTaggart and other 'dynamic' theorists of time have accused the B- and C-series of being deficient in their representation of time. They leave out, it is contended, that special quality of time that makes it 'time', namely its dynamism. As such, they are deemed 'static' theories. This has been a considerable point of contention amongst physicists in light of relativity theory's apparently static representation of time. The astronomer Arthur Eddington once remarked that *'[s]omething [i.e. passage] must be added to the geometrical conceptions comprised in Minkowski's world before it becomes a complete picture of the world as we know it*' [4] and more recently, the physicist Paul Davies has suggested that our very experience of time as passing '*is an aspect of time of great significance that we have [...] overlooked in our description of the physical Universe*' [5], both noting that there is something deficient in a static picture of time.

In response static theorists have held that static representations of time are rich enough to explain the various dynamic aspects of temporal experience and that no further property of 'passage' or 'dynamism' needs to be added to give a complete account of time. There are numerous ways to go. Firstly, it could be held that the passage of time is an illusion, that it merely appears to us that time passes when in fact it does not. Secondly, it could be held that our experience of time involves things like seeing motion and change in everyday objects, like a bird flying over one's shoulder and that there is no equivalent experience of sensing time itself as passing. Both such views have proven popular in the recent literature on the philosophy and psychology of time [6]-[8].

2.3. The key difference: Absolute simultaneity

Regardless of whether static time is taken to be deficient or not, there is a key difference between the dynamic and static pictures when it comes to relativity theory. The dynamic picture depends on a clear distinction between *moments* of time, specifically between the present moment and past and future moments. In order for there to be a privileged, unique, present moment, there need to be facts about which events are *simultaneous* with other events. For instance, what is going on *now* is the set of all things that are simultaneous with your reading of this sentence. Presentism, in particular, depends upon this idea of a global, unique, privileged 'Now' since it holds that what is going on 'Now' constitutes the sum total of existence. Relativity theory creates a key tension with dynamic time in so far as it gives up the idea of absolute simultaneity — whether or not two distant events are simultaneous depends upon a choice of reference frame from a family of 'equivalent' frames; there is no frame-independent fact as to whether the events really are simultaneous. This has the unwelcome consequence that there is no fact of the matter whether or not some event in some other location (e.g. the Andromeda Galaxy) is in the past, present or future. Static pictures of time are not so clearly troubled by this since there is nothing about events that depend upon whether they are past, present or future. Nothing 'comes into being' or 'happens' in their picture of time in the same way as they do for dynamic theorists and therefore nothing in their basic picture of reality is troubled by the relativity of simultaneity. However, the exact sense in which dynamic theories are troubled is somewhat nuanced and the paper will now move on to these key details.

3. Special Relativity and the Block Universe

It has been long-argued that Einstein's Special Theory of Relativity entails a static picture of time. Einstein himself once remarked that "*[f]or us believing physicists, the division into past, present and future has merely the meaning of an albeit obstinate illusion*," (Einstein in a 1955 letter to the family of Michele Besso, quoted in [9]) reflecting the idea of relativity theory as a proof of the Block Universe. Einstein's colleague Kurt Gödel talked in a similar fashion, remarking that from Special Relativity "*one obtains an unequivocal proof for the view of those philosophers who, like Parmenides, Immanuel Kant and the modern idealists, deny the objectivity of change and consider change as an illusion or an appearance due to our special mode of perception*" [10]. The mathematician Hermann Weyl again reflecting on the depiction of time in relativistic physics held that "*[t]he objective world simply is, it does not happen. Only to the gaze of my consciousness, crawling upward along the world-line of my body, does a section of the world come to life as a fleeting image in space which continuously changes in time*" [11]. Although this attitude of relativistic time being 'static' is common, arguments for it are not, and the arguments that exist are varied and nuanced. To consider these, the next section will first go through some of the key details of relativity theory.

3.1. The background

Einstein's 1905 presentation of the Special Theory of Relativity is based on two principles. First is the Principle of Relativity, which holds that the laws of nature take the same form in all inertial (non-accelerating) coordinate systems. This is also known as Galilean relativity, the principle Galileo Galilei famously appealed to in order to explain why one does not feel the motion of the Earth around the Sun. The idea is that a system in uniform motion will be indistinguishable from one at rest or at any other rate of uniform motion, meaning that no physical measurement can depend on how fast the relevant system (e.g. the laboratory one is in). (Properly understood, Galilean relativity tells us that the very idea of something being 'at rest' or having an absolute speed of motion lacks physical meaning.) Second is the Light Postulate, which holds that the speed of light in a vacuum is a constant, *c*, which is independent of the motion of the light source. Einstein took these principles to be curious in so far as they ought to be in contradiction — if we are travelling at different speeds relative to some source of light, then we ought to record different speeds for the light itself; if I am traveling at 99% of the speed of light, surely light travelling in the same direction should appear slower to me. Ultimately, such intuitions are undermined by Special Relativity. To preserve the Light Postulate whilst maintaining the Principle of Relativity, Einstein's Special Theory holds that spatial and temporal measurements can only ever have validity relative to some particular frame of reference, and a consequence of this is the relativity of simultaneity — there is no objective fact of the matter as to whether two distant instantaneous events occur at the same time. Instead, what is objective is the *spacetime interval* between the two events, their separation over four-dimensional spacetime as determined by the Minkowski metric. The spacetime interval between such events corresponds to a class of different pairs of spatial and temporal distances between the two events, relative to different inertial reference frames.

The simplest way to think of the geometrical structure of Special Relativity is in terms of a lightcone. Imagine switching on a point-sized lightbulb at point *x* in a vacuum, and the light radiating out spherically in all spatial dimensions over time. If this is depicted in terms of two-dimensional space and one dimension of time, one gets a cone expanding upwards, like the pink cone in figure 1. Let us call this the 'future lightcone' of *x*. One can also construct a 'past lightcone' for *x* which is the mirror image, expanding towards the past. The future and past lightcones give an intuitive picture of the spacetime interval between *x* and other possible events. Events that fall on the edge of either lightcone, such as event *l*, have a null or 'lightlike' separation from *x*, meaning that only things travelling at the speed of light (such as light itself) can travel from *x* to *l*. Points inside *x*'s past and future lightcones are possible events that are 'timelike', separated from *x* by an interval that can be traversed by things travelling slower than light (like me and you). For instance, *p* is in the 'past' of *x* in so far as something travelling slower than light could get from *p* to *x,* and *f* is in the 'future' of *x* in so far as something travelling slower than light could get from *x* to *f*. Finally, all the points outside the *x*'s lightcone are 'spacelike', separated from *x*, meaning that there is no traversable pathway between them and *x*. For example, to get from *s* to *x* or vice versa, something would have to travel faster than light.

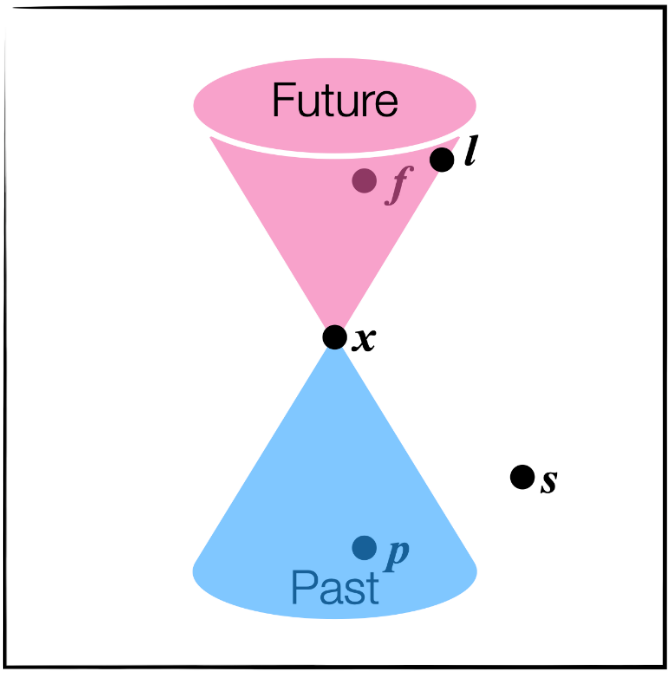

Figure 1. A lightcone, depicting timelike, null and spacelike spacetime intervals from point *x*.

Any timelike- or lightlike-separated pairs of events have an 'invariant' temporal ordering — their temporal order is agreed on by all permissible reference frames, meaning (for example) that it is an objective fact that *x* is earlier than *f*. However, any spacelike-separated pairs of events do not have an invariant temporal ordering. Different frames of reference can disagree as to (for example) the temporal order of *x* and *s*. On some frames, *x* is earlier than *s*, on some *x* is simultaneous with *s* and on some *x* is later than *s*. In other words, there is simply no fact of the matter as to the temporal order of spacelike-separated events. One way to make sense of this is to focus on causality. Causality is (in classical and relativistic physics) *local* in so far as one cannot instantaneously affect some distant object. In relativity theory, this causal locality carries over to time — since there can be no causal interaction between spacelike-separated events, it has no practical bearing as to the time order of those events.

3.2. The Metric Argument
The simplest sense in which relativity theory goes against the A-theory is that it appears to require a single metric for spacetime rather than independent metrics for space and time. Hermann Minkowski described his spacetime metric as having the following philosophical consequence: "*Henceforth space by itself and time by itself are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality*" [12]. This is a point about the mathematical structure of the theory, that while distances in space and time are not invariant between reference frames, the spacetime interval between two events is invariant, as determined by the Minkowski metric, which takes spacetime to be four-dimensional. Classical spacetime, by contrast, contains independent metrics for time and space, meaning that the theory treats temporal duration and spatial distances to be independent of each other. With the introduction of a single four-dimensional spacetime metric, the formal independence of space and time is lost, although there is still a formal distinction between space and time within Minkowski's metric with time represented using the opposite sign to the dimensions of space — the metric signature is either (+, +, +, -) or (-, -, -, +), depending on convention. Despite Minkowski's declaration of the end of 'time by itself', some have argued that this difference in sign between space and time in the metric reflects a key difference between space and time within Minkowski spacetime. For instance, H. Reichenbach [13] remarks that '*the world of Minkowski expresses the peculiarity of the time dimension mathematically by prefixing a minus sign to the time expression in the basic metrical formulae.*'

3.3. The Spatialisation Argument
The French philosopher Henri Bergson famously took issue with the treatment of time in early 20th century physics, accusing the likes of Einstein and Minkowski of 'spatializing time' through the use of 'static' representations of time. While such representations capture some features of time, they do not account for 'durée', the word used by Bergson to refer to the ineffable transience of felt time. However, there is a major worry that this type of argument rests on the issue of how time is represented using mathematical theories and diagrams. It is true that the kind of spacetime diagrams used in relativistic physics depict objects like you and I as stretched out across time with all moments in our lives afforded equal weight and without any clear depiction of animation or dynamism. However, the tools used to represent the world need not contain all of the features of the world that they represent. One can perfectly well depict a three-dimensional sphere by cleverly shading the two-dimensional surface of the paper in front of one. Similarly, one can hold that a 'spatial' image can be used to represent the various dynamic features of time that we appear to experience.

3.4. The 'Fixed Future' argument
In 1966 and 1967 two similar arguments were published that purported to demonstrate that Special Relativity is incompatible with our ordinary ideas of time. Hilary Putnam's paper [14], despite being published after C.W. Rietdijk's paper [15], notes that it was presented at the American Physical Society in January 1966, implying the precedence of Putnam's version. The notion of temporal

Journal of Physics: Conference Series **2877** (2024) 012078 doi:10.1088/1742-6596/2877/1/012078

precedence plays a central role in both arguments. Putnam and Rietdijk argue that relativity theory, given some basic assumptions, entail that the future is 'already' fixed and as such is incompatible with the idea of time as dynamic. According to Putnam:

[T]he problem of the reality and the determinateness of future events is now solved [by Special Relativity]. Moreover, it is solved by physics and not by philosophy. We [...] live in a four-dimensional and not a three-dimensional world, and that space and time - or, better, space-like separations and time-like separations - are just two aspects of a single four-dimensional continuum with a peculiar metric [...]. Indeed, I do not believe that there are any longer any philosophical problems about Time. ([14] p247)

And for Rietdijk:

[It follows from Special Relativity that] there is no free will; from this it follows, e.g., that the whole philosophy of existentialism is untenable. ([15] p343)

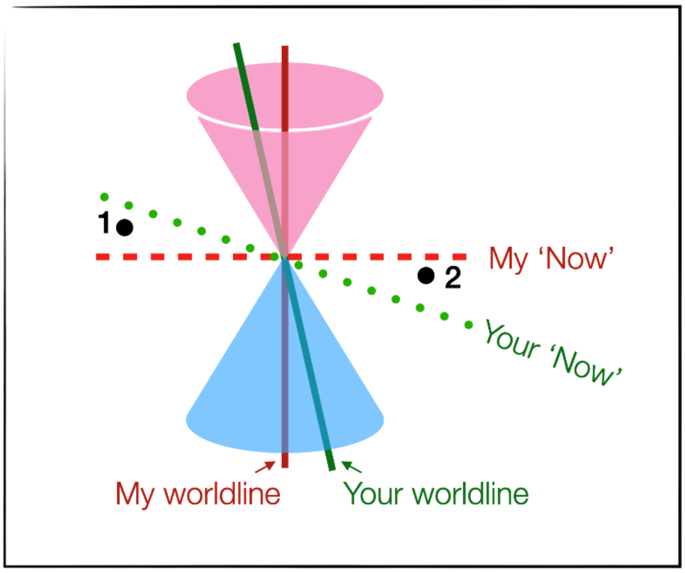

Figure 2. Depiction of different 'Now's relative to rest frames of relatively moving observers, and two spacelike-separated events '1' and '2'.

The shared sentiment in both arguments is that any attempt to introduce the idea of temporal becoming into a relativistic world will fail, entailing that even events in our local future should be deemed to be 'fixed' and not 'open'. Suppose one wants to hold that the past and present are 'fixed' — that there are facts about the past and present —, but that the future is 'open'. This corresponds to the central A-theoretic idea that the present and past have happened but the future has not happened. Then assume the case depicted in figure 2: you and I are travelling at different uniform velocities with our worldlines depicted running vertically on the diagram, such that our 'rest frames' (the coordinate systems relative to which each of us are at rest) are different. It follows from Special Relativity that my 'Now' — the set of objects that are simultaneous with me-now in my rest frame — is different from your 'Now' — the set of objects that are simultaneous with you-now in your rest frame. Crucially, our 'Now's disagree as to the status of spacelike-separated events 1 and 2. For my 'Now', 1 is in the future, and 2 is in the past — 2 has happened, and 1 is yet to happen. For your 'Now', the opposite is true.

This already shows up a key problem — our different rest frames disagree as to the unfolding of the Universe. But Putnam goes further by assuming principle of transitivity: if you-now are part of my reality, then anything that is real for you-now is real for me-now. This simple-sounding claim about reality leads straight into difficulties in light of the relativity of simultaneity. The problem is that if you-now are part of my 'Now', then the transitivity principle entails that everything on your 'Now' is part of my reality, but your 'Now' includes events that are in my future, and if further possible

Journal of Physics: Conference Series **2877** (2024) 012078 doi:10.1088/1742-6596/2877/1/012078

observers and their rest frames are introduced, we end up with a situation where transitive entails that any arbitrary event in my distant future comes out as being real. Putnam argues that ultimately any attempt to objectively carve reality into things that have happened and have not happened fails in light of relativity.

The obvious response, which Putnam anticipates, is that the transitivity principle just does not hold in relativistic spacetimes like ours, and that we have to defend a kind of temporal passage that does not require it. His response is that reality just does not work like that. If something is real for you, it should be real for me. If something is real for *anyone*, then it is just 'real'. However, there have been many such attempts to make sense of dynamic time in light of relativity theory.

3.5. Defences of dynamic time

Although the obvious response to such arguments may be to reject dynamic time and embrace static time, there are alternative options that have been explored and defended by philosophers. Most notably there are two main ways to deny that relativity theory rules out dynamic time:

(1) Deny dynamic time requires absolute simultaneity.
(2) Hold on to absolute simultaneity in spite of relativity theory.

There is also a third option that will ultimately be defended here, which is to deny that 'folk time' — the time or ordinary language and experience — is the kind of thing that can be incompatible with physical time (the time of physics), but that will be discussed in Section 5.

The philosopher of physics, Howard Stein [16] responded to Putnam's original argument and then decades later [17] to a resurgence of articles based on Putnam's argument by defending an account of the passage of time in terms of the structure of relativity theory. The key feature on Stein's account is that the relevant dynamic feature of time, which he calls 'temporal becoming' is a local feature of spacetime. Stein defines 'becoming' in terms of a relation between two events, effectively meaning that y has become as-of x just in case y is in x's past lightcone. This certainly does justice to one key desiderata of A-theories of time, as holding that there is a fixed, determinate past. The problem is that in so far as Stein's account defines a 'Now', it is one that has no spatial extent. Each point event in spacetime has its own 'Now' — the point of its location — with its past lightcone determining all those events that have 'become' relative to it. But this is some way short of the full picture of time demanded by dynamic theories. Craig Callender [18], [19] emphasises that Stein's relativistic account of temporal becoming falls apart if one tries to add one extra feature — that there is any spatial extent of the Now or any other observer who is also in the 'Now'. And even if one is willing to give up the idea that the Now spreads beyond an infinitesimal point in space, there is the further problem of how to think of the Now as dynamic or animated. How does time pass if every point in spacetime has its own Now? There are clear conceptual problems with such an idea, and any such metaphysical picture will have to be complicated and in various respects counterintuitive.

An alternative response that has received some attention is to adopt a 'Lorentzian' interpretation of relativity theory. Hendrik Lorentz's name is attached to the central symmetry of Minkowski spacetime, giving the set of transformations that take sets of spatiotemporal measurements from one inertial frame to another. Lorentz's work preceded Einstein and Minkowski's interpretation of the Lorentz transformations, and whereas the Einstein-Minkowski view is that only the spacetime interval is objective with spatial distances and temporal durations between events being only frame-relative, Lorentz took both spatial distances and temporal durations to be objective. For Lorentz, the Lorentz transformations tell one how one's measurement results are affected by motion relative to the aether. In other words, the faster one moves, the more one's measuring instruments (e.g. one's metre stick and clock) are distorted due to the motion, and as such one's results are affected by a factor determined by the Lorentz transformations. On this picture, there is a privileged frame of reference, a correct way to represent spacetime in terms of instantaneous moments of time. However, relativistic effects prevent one from being able to establish by measurement *which* is the privileged frame. So when we consider my 'Now' and your 'Now', it might be the case that your 'Now' is the correct one and mine is not.

Journal of Physics: Conference Series **2877** (2024) 012078 doi:10.1088/1742-6596/2877/1/012078

Lorentz himself appeared motivated by a classical picture of time, remarking that '*[m]y notion of time is so definite that I clearly distinguish in my picture what is simultaneous and what is not'* ([20] p221).

Unsurprisingly, many A-theorists have adopted a 'neo-Lorentzian' reading of relativity in order to preserve the idea of a global flowing time. What this brings to the fore is that it is tenable to hold a classical picture of dynamic time, but it requires a commitment to an outdated interpretation of relativity theory. There are many virtues of the Einsteinian interpretation: it incorporates Lorentz symmetry without requiring a mechanism by which measuring instruments distort, it dispenses with the undetectable aether and it was generalised to a theory that gives our best description of gravity — General Relativity Theory. The main motivation for clinging to the Lorentzian view appears to be to maintain a classical view of time. However, since new theories in physics invariably force us to update our conceptions of things like space, causation, motion, identity and so on, it seems reasonable to also update our conception of time in a similar manner.

4. General relativity and time

To recap so far: the Einstein-Minkowski reading of relativity theory gives a picture of spacetime that does not accord to a classical picture of the world as divided up into global moments of time. This clashes with the philosophical view of time as objectively divided into regions of past, present and future, with a dynamic, moving present moment. Although there are ways to maintain such a dynamic picture of time in light of relativity, the main options are to regard the 'Now' as something counterintuitively 'local' in space, or to adopt an outdated interpretation of Lorentz symmetry. There is an alternative possibility, however. The 'Special' Theory of Relativity is just that, *special*. It is not a global theory that accounts for gravitational interactions, and in order to extend the theory, Einstein developed the General Theory of Relativity, which some have argued reopens the door to the idea of a privileged frame of reference relative to which time passes. Recognising this potential way back for dynamic time, Einstein's colleague at Princeton, the logician and philosopher Kurt Gödel produced an argument [10] that dynamic time fares even worse in light of General Relativity. Ultimately Gödel took time to be 'unreal' or 'ideal' – a concept we have that fails to latch onto reality.

After befriending Einstein at Princeton, Gödel was asked to write a piece about the philosophical contributions made by Einstein's work in physics. To say that Gödel took this to extremes would be an understatement. He produced a proof that the General Theory of Relativity allowed for the existence of 'closed timelike curves' (CTCs), paths in spacetime that loop back on themselves that can be taken by objects travelling slower than the speed of light. Gödel's solutions to the Einstein Field Equations are atypical because they describe 'rotating' universes, where matter within the Universe is in an extreme relative motion, resulting in a sufficient distortion of the lightcone structure to allow a body to move always into its own future lightcone but end up back where it started. In other words, Gödel had shown that General Relativity allows for the possibility of time travel into the past.

Although Gödel was careful to argue that this result does not entail that time travel is a practical possibility in the actual world in which we live (either because the actual world might not contain CTCs or if it did there might be no way to actually traverse one into our local past), he derived a philosophical argument that the mere physical possibility of CTCs showed that time does not exist. Ultimately, what Gödel meant is that a very standard, A-theoretic understanding of time is not tenable given the possibility of CTCs. Gödel thought of the standard picture of time to be of an "*infinity of layers of 'Now' which come into existence successively*," which he also termed the 'objective lapse of time'. [10] This sounds very much like the idea of presentism and accordingly, Gödel first considered this conception to be troubled by Special Relativity, for much the same reasons as have been considered here. However, Gödel thought the Special Relativity objection could be avoided, at least in principle, since the strict equivalence of frames of reference is less well-motivated in General Relativity. He noted that one might have strong naturalistic reasons for taking something like the rest frame for the centre of mass of the Universe to be 'privileged' over other possible reference frames. But he argued that this defence cannot be used against his rotating universe argument. Crucially, in one of his rotating universes, one cannot even divide the world into moments of time. Any attempt to

Journal of Physics: Conference Series **2877** (2024) 012078 doi:10.1088/1742-6596/2877/1/012078

produce a global slice of time (a 'Now') fails since a single object could be multiply located on any such slice, and other causal difficulties.

The key step in his argument is that Gödel supposed that whether or not time really passes and whether or not the future and past exist could not be a matter of contingency. Either time passes *in all physically possible worlds* or it does not pass in any. Or alternatively, either the passage of time in our world is independent of the specific arrangement of mass-energy or time does not pass. In his words:

> The mere compatibility with the laws of nature of worlds in which there is no distinguished absolute time, and, therefore, no objective lapse of time can exist, throws some light on the meaning of time also in those worlds in which an absolute time can be defined. For, if someone asserts that this absolute time is lapsing, [they accept] as a consequence that, whether or not an objective lapse of time exists […] depends on the particular way in which matter and its motion are arranged in the world. This is not a straightforward contradiction; nevertheless, a philosophical view leading to such consequences can hardly be considered as satisfactory. ([10] p562)

Gödel was appealing to the intuition that the basic properties of time cannot hinge upon the way matter happens to be arranged in the world. If there is even the possibility of matter-energy being arranged in such a way to make the Universe inhospitable to (1) global moments of time and (2) a distinction into an accessible 'future' and inaccessible 'past', then one should give up the idea of time as dynamic. This is a particularly interesting argument, since it trades on our intuitions about possibility and contingency. Some have simply rejected Gödel's conclusion on the grounds that any time-travel solutions to General Relativity should be rejected as unphysical. For instance, Stephen Hawking argued that there is good reason to regard these solutions as inconsistent with other physical principles. Others have suggested that time travel itself is logically impossible and that such solutions should be ruled out on this ground.

5. Folk time versus Physical time? A case for compatibility

To take us back to our initial problem: is time real in light of relativity theory? There is no doubt that relativity theory gives a different picture of physical time than that given by classical physics. But firstly, as seen in Sections 2 and 3, there are good reasons to think that 'static' representations of time do not actively leave out any essential property of time. Secondly, it is far from clear that relativity undermines our folk descriptions of time or our experience of time in a new way. Time is a very personal concept and updates to our picture of physical time can sound more radical than updates to our picture of fundamental particles or forces. We are well acquainted with microphysics clashing with basic principles previously held about the world, such as seemingly solid, stationary objects being comprised of unimaginably small, sparse, and moving particles. But for various reasons, time is something that we feel acquainted with and tied to our basic conceptions of reality and the nature of our experience and existence in the world. In light of this, this paper will end with a speculation about how to adopt a compatibalist attitude between relativity theory and dynamic time.

To start with, one can distinguish between three different concepts of time. Firstly, physical time is the various ways in which time is understood by contemporary fundamental physics, such as relativity theory and quantum mechanics. Secondly, experienced time is the various ways in which one experiences seemingly temporal things in the world, such as the change and motion of objects, and sequences in which events appear to happen. Thirdly, folk time is the picture of time that accords to how one ordinarily talks and thinks about time, largely in line with how one experiences it, but together with metaphorical notions like time flowing like a river, which are less obviously aspects of experience. [21]

What is seen in the case of relativity theory is an account of physical time that clashes with a standard folk view of time — it is hard to make sense of how reality can be composed of a moving, global present moment without it running into conflict with the relativity of simultaneity. But folk theories of the world are often in conflict with science and for the most part, their usefulness does not depend upon their scientific accuracy. When you say to me '*time flows like a river*' or more likely ‘*time has flown this year*’, I know what you mean and I do not take you to be making a deep claim about the structure of reality. Moreover, it would be odd for me to respond to you that relativity theory dictates that you no longer make such proclamations.

Our experience of time itself is limited in various ways. In the case of the ‘Now’, although it might appear reasonable to hold that experience motivates the idea of a global Now, there is good reason to doubt this. Our experience of the world is highly local — we cannot instantaneously experience things that are arbitrarily far away. And our notion of simultaneity is very approximate. If I phone someone in Australia, I take it that we are sharing a present moment in so far as we are able to communicate back and forth. I can send messages to people in the future but cannot receive messages back, so I can deem them to not share my present. But when it comes to the kinds of example used in arguments concerning special relativity and static time, one is dealing with spacelike-separated regions of spacetime between which there can be no such communication, so the intuition that such regions can share a unique present moment is somewhat over-stretched. As such, there are plausible grounds for holding that the idea of reality as ordered in terms of shared ‘present’ moments, of a fixed past and open future, and of time as flowing, as a useful and meaningful local concept of time for people like us without it being a candidate for how time is independently of these conditions. There is room in other words for taking physical time and folk time to be playing different games and to not be the kinds of thing that should be seen as in competition in the first place.

References

[1] Einstein A 1905 On the electrodynamics of moving bodies *Annalen der Physik* **322** 891
[2] McTaggart J M E 1908 The unreality of time *Mind* **17** 457–74
[3] Farr M 2020 C-theories of time: On the adirectionality of time *Philosophy Compass* **15** e12714
[4] Eddington A S 1927 *The Nature of the Physical World* (Cambridge: Cambridge University Press)
[5] Davies P 1996 *About time: Einstein’s unfinished revolution* (Simon and Schuster)
[6] Deng N 2013 Our experience of passage on the B-theory *Erkenntnis* **78** 713–26
[7] Farr M 2020 Explaining temporal qualia *European Journal for Philosophy of Science* **10** 8
[8] Baron S, Cusbert J, Farr M, Kon M and Miller K 2015 Temporal experience, temporal passage and the cognitive sciences *Philosophy Compass* **10** 560–71
[9] Zeh H D 1992 The Physical Basis of The Direction of Time (Springer, Berlin, Heidelberg)
[10] Gödel K 1949 A remark on the relationship between relativity theory and idealistic philosophy. In P Schilpp ed. *Albert Einstein: Philosopher-Scientist*, *volume 4 of Library of Living Philosophers* pp 555–62 (La Salle, IL: Open Court)
[11] Weyl H 1963 *Philosophy of Mathematics and Natural Science* (New York: Atheneum)
[12] Minkowski H 1923 Space and time. In H A Lorentz, A Einstein, H Minkowski and H Weyl eds. *The Principle of Relativity* pp 75–91 (London: Metheun)
[13] Reichenbach H 1957 *The philosophy of space and time* (Dover)
[14] Putnam H 1967 Time and physical geometry *The journal of Philosophy* **64** 240–7
[15] Rietdijk C W 1966 A rigorous proof of determinism derived from the special theory of relativity *Philosophy of Science* **33** 341–4
[16] Stein H 1968 On Einstein–Minkowski space-time *The Journal of Philosophy* **65** 5–23
[17] Stein H 1991 On relativity theory and openness of the future *Philosophy of Science* **58** 147–67
[18] Callender C 2000 Shedding light on time *Philosophy of Science* **67** S587–99
[19] Callender C 2017 *What makes time special?* (Oxford: Oxford University Press)
[20] Lorentz H A 1927 *Problems of Modern Physics* (Boston: Ginn)
[21] Farr M 2023 The Three-Times Problem *Frontiers in Psychology* **14** 1130228