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HOW THE RELATIVITY OF SIMULTANEITY SUPPORTS BLOCK TIME THEORY

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ABSTRACT

Most things in the universe we can understand to be physical phenomena processed by one or more of our physiological senses. However, the notion of time has always intrigued philosophers and physicists alike because of its intangibility and its omnipresence in our phenomenological experience. Intuitively, we assign the present moment special ontological status because it is this instant in time when we feel that we are freely capable to enact our will. In this paper, I support the eternalist philosophical approach, or block time theory, wherein all points in time share the same ontological status. By means of special relativity, Minkowski space, and inspired by the classic Rietdijk-Putnam argument, I show how the presentist view of time fails to make sense when speaking of ontological properties of the universe.

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Chapter 1

Introduction

The philosophical study of space and time has brought forth some of the most complex questions the universe has to offer. Despite their sophisticated nature, we use our perceptual understanding of space and time quite frequently. We routinely measure lengths, record time durations, calculate velocities, and produce geometric maps without engaging in a serious inquiry as to what the ontological natures of space and time actually are. As scientific developments have been made over the centuries and the human understanding of the physical world around us has matured, questions about the essence of space and time continue to mystify some of the brightest philosophical and scientific minds. The enigmatic nature of space and time raises various questions, such as whether space and time exist independently of the mind, whether they exist independently of each other, and whether there is a rational explanation as to why time's asymmetry and unidirectional motion do not parallel space's isotropy and homogeneity.

My goal in this paper is to defend particular answers to these questions in terms of relativistic physics. In particular, this paper's discussion of time's philosophical dimension will be motivated by the issue of whether or not all events, past, present, and future, are real. The criteria for what is real, and whether any ontological distinctions can be drawn among the various tenses, will be defined in stages, as I use relativistic physics to help pinpoint what we mean by tensed language and the quality of realness. There is a general understanding among philosophers of time that there are three competing camps when it comes to the issue of which temporal states are real. The first theory is known as presentism, and it can loosely be traced back to the philosophy of Heraclitus.[1] Presentists believe that only that which is present is real, and those events of the past and present were real or will be real, respectively. Yet the present holds a privileged status because only events existing in the momentary present possess any ontological realness. What is meant by the term "present" will of course be described more rigorously throughout the paper. Defenders of this view, that the past and future are unreal, include individuals like Arthur Prior and Ned Markosian (Markosian 2004). The second theory goes by several names, but it is most often labeled as possibilism or the growing block universe theory. In this view, everything contained within the past and the present is real, while that which is in the future is deemed unreal. Contemporary proponents of this theory include C.D. Broad and Peter Forrest (Braddon-Mitchell 2004). These first two views of time initially appear plausible because they capture the perceptual experience of humans and the process of becoming. People view the present as being a unique temporal frame that creates a definitive divide between that which has occurred and that which is yet to transpire.

The last view, and the one that I will champion in this paper, is the theory of eternalism, also known as the block universe or block time theory. This stance maintains that the past, present, and future are all equally real. While this view has ancient roots in the writings of Greek philosopher Parmenides, with the emergence of the theories of relativity, many philosophers and physicists have also defended this view, despite the fact that the other stances are seemingly

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[1] Around 500 B.C., Heraclitus writes, "Everything flows and nothing abides. Everything gives way and nothing stays fixed. You cannot step into the same river, for other waters and yet others, go flowing on," (Heraclitus and Robinson 1991, 17). Heraclitus emphasized the flow of time, and flow implies a change in states. This change can be understood as the present flowing through time.

more intuitive.[2] A long line of physicists have endorsed the block universe view, while philosophers tend to be more skeptical of the theory. Physicists Olivier Costa de Beauregard, Thomas Gold, Peter Atkins, Paul Davies, and more recently Julian Barbour have endorsed either an idealist view of time or a fully-fledged version of the block universe (Weinert 2004). First, I will detail the chronological journey of humans and their judgments about the character of time. In any philosophical debate, it is important to recall the dialogue that generated the divergent schools of thought, and I hope to use this as a way to introduce my defense of eternalism. I will begin by giving a brief description of humans' understanding of time from Aristotle through Newton, and from there, I will introduce Albert Einstein's theory of special relativity as well as Hermann Minkowski's bringing together of space and time into a unified, four-dimensional manifold.[3] Afterwards, I will use these physical and mathematical theories to highlight the philosophical approach to the ontological nature of time that best complements physics as we now understand it. My hope if that by the end of this paper, readers will understand and

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[2] Around a generation or so following Heraclitus, Parmenides stated, "There remains then, but one word by which to express the [true] road: Is. And on this road there are many signs that what is has no beginning and never will be destroyed: it is whole, still, and without end. It neither was nor will be, it simply is—now, altogether, one, continuous…" (quoted in Savitt 2014). This static and unified vision of the universe parallels the unchanging and immobile version of time in block universe theory.

[3] Hermann Minkowski was a German mathematician who developed a geometrical theory of numbers, and is primarily remembered for his contributions to relativity. He was the first to interpret his student Albert Einstein's theory of special relativity in geometric terms as a four-dimensional manifold, now known as Minkowski space. Einstein initially thought that his math professor's geometric interpretation was merely mathematical craftiness, not indicative of any meaningful description of reality. It was only after Minkowski passed away and Einstein began his work on general relativity that Einstein realized how necessary and expressive Minkowski space could be.

appreciate a meaningful pattern of gradual progressions towards a block universe view.

Chapter 2

Historical Development of Time

The study of physics largely stems from the experimental observation and mathematical understanding of dynamical systems. As human beings, we perceive change throughout the universe, and it is this observable change that gives rise to our conception of time. The motion of bodies, in particular, was a type of change that early natural philosophers were able to observe. Because motion is a fundamental and pivotal concept in physical theories, it is necessary to have a tight grasp on what motion is and how different types of motions resemble or differ from one another. For Aristotle, the nature of an object could be described by the motion exhibited when no forces are applied to it. This way of understanding the nature of an object by means of change and locomotion rather than its atomic constituents was unique to Ancient Greece (Maudlin 2012). Aristotle proposed that when a rock is left to its own devices, it would fall downward towards the center of the earth. Likewise, a fire would rise in a straight line from this same center point. Overall, the four elements that Aristotle believed to exist each exhibited its own natural motion; earth and water were inclined to move downward toward the center of the earth, and fire and air were inclined to move upward from the center of the earth. Therefore, if the universe were left entirely unchanged by outside agents, the four elements would naturally segregate out into four concentric spheres, with an inner sphere of earth surrounded by a sphere of water, then air, and culminating with a sphere of fire. The heavenly bodies, for Aristotle, did not fit into this scheme, and so he proposed that these objects were made up of a substance called aether whose natural state was to traverse space in uniform circular motion such that they always returned to the same place (Aristotle and Hope 1961). This type of motion implies that any change in physical space is simply change made in reference to the center of the spherical universe. In other words, Aristotle's conception of the universe takes on the shape of a sphere, and so this sphere's center is a geometrically privileged point in space to which all motion refers. Aristotle's physics assumed an absolute structure of space in which absolute time was able to exist (Maudlin 2012). In fact, Aristotle even maintained that there was an absolute privileged rest frame: the earth. Thus, we see that the intellectual tradition that gave birth to contemporary physics began with a concrete rigid understanding of space and time.

Aristotle's cosmological view of the universe was held as the standard until the 17th century, when the Copernican revolution began to usher in a new understanding of how the universe operates. The Copernican revolution, culminating in the laws of Newtonian mechanics, abolished the idea of an absolute rest frame, though it upheld the idea of absolute time. Firstly, Newtonian mechanics abolished the idea that there are four (or more accurately, five, if we include aether) different elements whose properties and modes of locomotion differ from one another. This is apparent in Newton's axioms of physics that are laid out in his *Philosophiæ Naturalis Principia Mathematica* of 1687. Newton's first law asserts that every body preserves its state, either of rest or of uniform motion in a straight line, except insofar as it is compelled to change its state by impressed forces. Thus, no reference is made to earth, water, fire, wind, or aether. A body of matter is simply a body of matter, and Newton's laws claim to categorize *every* body (Newton 2002). Furthermore, the *Principia* does not suggest any sort of "natural" motion other than the idea that a body will maintain its motion, either at rest or in a straight line with constant speed, unless acted on by an outside force. With no natural direction of motion, there is no place in the universe to which any body's motion must be referred. Newtonian mechanics does not require that space have a special central point.[4] Newton's physics also helped to introduce the idea of inertial motion—motion that is physically equivalent to rest. Because there is no privileged frame of reference, an object at rest is in the same state of motion as an object moving at a constant speed unaffected by external forces.

Nonetheless, though there is no privileged spatial point in the universe, Newton does employ the notion of absolute space. Prior to Newtonian mechanics, various ideas were purported that differed from the absolute space that Newton conceives. In particular, Descartes proposed that the essence of matter is the attribute of extension. According to Descartes, one cannot conceive, outside of mathematical idealism, any type of matter without its extended size and shape in the universe (Descartes and Reynolds 1988). But since he also saw extension as the essence of space, he concluded that space and matter are physically manifested as one and the same thing. Therefore, a vacuum of space is not only an impossible reality, but also an idea impossible to even imagine in physical terms. In Descartes' view, the universe consists of space that is full of mobile matter wherein certain pieces of matter can move relative to other pieces of matter. Thus, matter moves in circuits or vortices, and space and matter are inseparable. Essentially, Descartes' spatiotemporal understanding of the world states that the universe is in

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[4] In this view of absolute space, space itself is deemed to be immobile, and matter is viewed as being the content that can move *through* this space. Points of space remain the same through time, and thus time's fluidity is contrasted with space's rigidity. This distinction between time's flowing character and space's immutability leaves time intervals as the only observer invariant properties in Newtonian mechanics.

fact nothing more than a compilation of material bodies jostling in motion without any gaps. So although many may now reflect upon Newton's abstraction of space and time and deem it to be rudimentary, by looking at early philosophers preceding Newton, we can see just how revolutionary Newton was with his mechanical theories. Newton's space and time only seem self-evident because society has been exposed to it for so long.

Newton's absolute space could be constructed geometrically by a Euclidean structure of space extending out infinitely in three directions, each direction orthogonal to the other two. This three-dimensional space exists at every moment in time, and the same points of space persist through time. In essence, Newton had to address what it meant for a body to truly be at rest. By using absolute space, one can reason that individual points of space retain their unique identity through time, and so a body is at absolute rest when it occupies the same points of absolute space over a period of time. Furthermore, for an object to be said to have uniform motion as it travels in a straight line, the idea of absolute time must be introduced. In order for motion to be uniform, it must cover the same amount of distance given the same amount of time. Therefore, there must be an objective determination as to how much time it takes for a body to move in space. Newton postulated that absolute time in itself has direct physical meaning that can be represented by a one-dimensional mathematical continuum in which there is a single, ordered sequence of instants that forms the totality of time's progression. Time, then, can simply be represented by the real number line. What this implies is that if there is a particular amount of time between events 1 and 2, and if there is a particular amount of time between events 3 and 4, then there is an objective fact about the ratio between these two intervals. After Newton published the *Principia*, people presumed that time is a part of physical reality that flows uniformly and continuously without any influence from outside factors (Kuhn 1957). While Aristotle drew up a universe with absolute space and absolute time, proclaiming earth as the absolute rest frame, Newton dismissed this absolute rest frame, although he maintained absolute space and time (Grosholz 2011).

Chapter 3

Special Relativity and Minkowski Space

After roughly two hundred years following Newton's contributions to physics, during the late 19th century, Newtonian mechanics became subject to critique and revision. While it is effective in describing the human experience of kinematics at a basic level, Newtonian mechanics do not apply when bodies begin to move at high speeds that rival the speed of light, or when the objects in question become very large. The need to improve upon Newtonian mechanics arose in the 1860s when Scottish physicist James Clarke Maxwell came up with a set of partial differential equations, now known as Maxwell's equations, to describe electromagnetism and electromagnetic waves. While none of these equations explicitly include the speed of light, Maxwell combined his equations to produce a wave equation for electromagnetic waves. Like any other wave equation, this expression could be used to predict the speed at which electromagnetic waves travel in a vacuum. In fact, by manipulating Maxwell's equations, the speed of light in a vacuum turns out to be equivalent to

$$\mathrm{v} = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$$

where constants ϵ_0 and μ_0 represent the permittivity and permeability of free space, respectively. It appears that Maxwell's equations are able give a value for the speed of light without indicating the medium through which light is propagating at this calculated speed. With no medium, or no reference frame to refer to, it was thought that one is unable to calculate a definitive speed for some body in question. The idea of a universally constant speed does not make any sense in the context of Galilean relativity. This enticed many physicists to claim that light and all electromagnetic phenomena occurs in a specific reference frame called the ether.[5] Thus, the speed of light would be relative only to this ether (different from the aether of Aristotle).[6] Perhaps this ether is what Newton was referring to when he wrote about absolute space centuries earlier. Eventually, however, the Michelson-Morley experiments of 1887 showed that the speed of light obtained by manipulating Maxwell's equations is independent of the experiment's physical orientation towards the hypothesized ether. As a result, the idea of an ether does not hold true after empirical experimentation. The notion that electromagnetic waves travelled at a constant value without needing to introduce a medium to which the speed is relative seemingly contradicts

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[5] In more detail, the way one can derive the speed of light from Maxwell's equations is as follows,

$$\textit{Consider } \nabla\ x\ B = \mu J + \mu\epsilon \frac{\partial E}{\partial t}$$

$$\textit{Here } \mu\epsilon = \frac{1}{c^2}$$

$$\textit{In a vacuum } J = 0 \textit{ so that } \nabla\ x\ B = \frac{1}{c^2}\frac{\partial^2 E}{\partial t^2}$$

$$\textit{Take the curl of } \nabla\ x\ E \textit{ to obtain } \frac{\partial}{\partial t}\nabla\ x\ B = \frac{1}{c^2}\frac{\partial^2 E}{\partial t^2}$$

$$\textit{Using the vector identity } \nabla\ x\ \nabla\ x\ E = \nabla(\nabla \cdot E) - \nabla^2 E \textit{ and the first Maxwell equation } \nabla \cdot E = 0,$$

$$\textit{we get } \nabla\ x\ \nabla\ x\ E = -\nabla^2 E \textit{ so that } \nabla\ x\ \nabla\ x\ E = -\nabla^2 E = \frac{1}{c^2}\frac{\partial^2 E}{\partial t^2}$$

$$\textit{which is the wave equation } \left(\nabla^2 - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\right)E = 0 \textit{ in d'Alembertian form}$$

$$\textit{This wave equation can be reduced to } 1\textit{st order wave equation terms traveling in opposite directions}$$

$$\left(\nabla^2 - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\right)E = \left(\nabla - \frac{1}{c}\frac{\partial}{\partial t}\right)\left(\nabla + \frac{1}{c}\frac{\partial}{\partial t}\right)E$$

which evidently shows propagation at constant c where $\in_0$ and μ_0 are constant.

[6] There does not appear to be a consensus on the spelling of ether or aether when referring to either Aristotle's or early modern physicists' use of it, and so I elected to use the difference in spelling here as a way of distinguishing them for convenience's sake.

Newtonian mechanics. This contradiction puzzled physicists until Einstein introduced his theories of relativity.

We now know that Einstein’s theories of relativity, as well as quantum mechanics, more accurately describe physical motion, though which of the two modern theories is useful depends upon the context of the particular physical situation. For the purposes of this paper, I would like to discuss the theories of relativity in terms of their philosophical implications, though discussing quantum mechanics would prove no less relevant or interesting. Einstein began his special theory of relativity (hereafter abbreviated as STR) by taking two fundamental and generally agreed upon propositions: the independence of physical laws and the constancy of the speed of light. These two grounding postulates of STR that Einstein initially proposed in 1905 can be summarized as follows:

(1) The laws of physics are the same in all inertial reference frames.

(2) The speed of light in a vacuum is equal to c, independent of the motion of the source of the observer.

The first postulate asserts that no particular inertial reference frame is preferred over another. This coincides with Newton’s elimination of a privileged spatial reference point that Aristotle introduced. The second postulate of STR distinguishes light in a vacuum from other kinds of waves (Einstein 1961). If someone who is at rest relative to a fixed observer were to turn on a flashlight, it is clear that this light would travel at c. Now if somebody else who is moving at velocity v relative to the fixed observer turns on a flashlight, it is intuitive to think that the fixed observer would see this light traveling at $v + c$. However, this light would, just like the first scenario, travel at c, and Einstein affirms that the vacuum speed of light is the same in all inertial frames. These postulates, while they appear simple, imply complex and unexpected consequences. The results from STR contradict our intuition. In fact, STR reveals that our ideas about relative velocities are approximations that only hold true when the speeds in question are significantly small compared to c.[7] Though it conflicts with our intuition, STR has been experimentally verified on numerous occasions.

By way of STR, the Galilean transformations of Newtonian mechanics are replaced by Lorentz transformations. The general relation between spacetime coordinates x, y, z, and t of an event seen in reference frame 1 and the coordinates x', y', z', and t' of the same event as seen in reference frame 2, which is moving with uniform velocity relative to 1, can be explained by the Lorentz transformations. These transformations are named after Dutch physicist H.A. Lorentz who derived them, surprisingly, prior to Einstein's theory. Just like Newtonian mechanics are invariant under Galilean transformations, so too under STR, the laws of physics are invariant under Lorentz transformations. I will briefly explain Lorentz transformations so as to make the matter more clear. If a primed reference frame is moving at a constant speed v in the +x-direction relative to a non-primed reference frame, the relationship between their spatial coordinates is described by the Lorentz equation, as follows:

$$x' = \gamma(x - vt),\ y' = y,\ z' = z,\ where\, \gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

The transformation of the time dimension is described by,

$$t' = \gamma\left(t - \frac{vx}{c^2}\right)$$

where γ is the same as before. As a result of these transformations, instances of time dilation and length contraction occur wherein "time slows down" and "lengths contract" at speeds close to that

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[7] Special relativity thus satisfies the correspondence principle, since it reduces to Newtonian mechanics in the limit of velocities small compared to the speed of light.

of light. So whereas space and time were once thought of as constant in classical dynamics, this no longer holds true in STR; both are dependent upon the speed of the inertial frame. What *does* remain invariant throughout the special relativistic mechanics and the Lorentz transformation is the spacetime interval, Δs, such that

$$(\Delta s)^2 = c^2\Delta t^2 - (\Delta x^2 + \Delta y^2 + \Delta z^2)$$

In other words, two events may occur to observer A as happening over the duration of period *t* with distance *x* in between them, and observer B might perceive these events as happening over the duration of *t'* with distance *x'* in between them. Nonetheless, observers A and B will agree on their calculations of this value, $(\Delta s)^2$.

Typically, three dimensions of Euclidean length and a time interval are needed to specify where and when an event occurs. However, because in STR time and space are heavily intertwined, the idea of a single continuum known as spacetime emerges. As might be expected, Euclidean geometry, which inherently ignores time, is not convenient in STR. As STR replaces classical dynamics, Newtonian space and time are replaced by a flat spacetime, which as previously mentioned, is known as Minkowski space. In the same way that Euclidean geometry is useful for expressing the symmetry of inertia in Newtonian mechanics, Minkowski space geometry was developed as a way to express the symmetry of inertia in STR. While the values of spatial dimensions and time will differ amongst reference frames due to length contraction and time dilation, Minkowski spacetime ensures that all frames of reference will agree on the total distance in spacetime between events.

Before STR, Newtonian dynamics described how two events are separated by two types of intervals, one being the distance traversed and the other being the lapse of time. Even in this pre-relativity era of physics, it was believed that while distance intervals are relative, simultaneity and any time interval is invariant under change of inertial reference frame i.e. $\Delta t' = \Delta t$ in all cases in pre-relativistic physics. As a result of the postulate of spacetime as one entity, it becomes clear that time and space are entities perceived differently by each observer, and there is not a single cosmic order in this regard. But while STR certifies the weightiness of identifying the framed perspective when analyzing the spatial and temporal qualities of an environment, it in no way suggests that differing perspectives gives rise to illusions of space or time. The effects of length contraction and time dilation are not metaphysically akin to the effects of distorting mirrors that one may find at a carnival. The image produced by a curved mirror is truly a distortion because a person next to the object whose image is reflected by the mirror would not observe the object to be flattened or stretched. Yet for the observable effects produced by STR, philosopher of time at the University of Liverpool, Barry Dainton, writes that "if you and I pass one another travelling at near-light speed, and I look across and see you flattened and slowed, I am not seeing a distorted image of you. I am seeing you as you truly are, just as someone who shares your velocity and who doesn't see you flattened and slowed *also* sees you as you truly are," (Dainton 2010, 268). Objects and processes still possess determinate shapes and durations; STR simply renders them frame-relative properties. To those unaccustomed to applying STR, these aforementioned results can seem like deceptions wherein objects only look they are being flattened or slowed, as opposed to actually holding these properties. It needs to be understood that the effects of STR are not illusions and they are quite real. For instance, if an object with a proper length of 10 meters is moving at relativistic speeds and is approaching a room that is slightly less than 10 meters long, this object will, in fact, fit in the room.[8] Minkowski space makes temporal separation relative to the frame of

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[8] An object's proper length refers to the length of an object as measured in the object's rest frame.

the observer, so that the notion of a temporal separation between two events is not well defined. Consequently, the concept of “same time” loses its meaning. Aristotle introduced absolute time with an absolute rest frame. Newton maintained absolute time and annulled the need for an absolute rest frame. Now, with Einstein’s STR, there is no absolute time! There is merely an observer-dependent conception of time where only spacetime intervals are invariant.

Chapter 4

Relativity of Simultaneity

Minkowski space is a representation developed by means of mathematical physics to integrate Euclidean space and time into a four-dimensional manifold wherein the spacetime interval between any two events as measured by $(\Delta s)^2$ is independent of an observer's inertial frame of reference.[9] Since Minkowski space is a direct consequence of the postulates of STR, it is important to use a Minkowski space representation of worldly events to understand what exactly STR implies about the temporal and spatial nature of the universe. Imagine some observer A. Allow the Minkowski space for this individual to be illustrated by a horizontal axis representing space and a vertical axis representing time (multiplied by constant c, the speed of light). This is a way of reducing a four-dimensional scenario into a two-dimensional one, and we are able to do this when all three points in Euclidean space are treated as one aspect of location in spacetime. Now, imagine some observer B who is moving at relativistic speeds and intersects with A at some point in spacetime. Due to the fact that they are moving relative to each other, A and B will not have the same spacetime axes. If we take observer A to have a reference frame oriented in such a way that the spatial axis is parallel to the bottom of the page and the time axis perpendicular to this spatial axis, we can determine the axes of observer B by way of the Lorentz transformations. Using the previously stated Lorentz equations for x' and t', plotting the x',t' space axis and the x',t' time axis reveals that the time axis has a slope of v and the space axis has a slope of $\frac{c^2}{v}$, thus meeting at an angle less than 90°. Without loss of generality, allow

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[9] Note that Minkowski space differs from four-dimensional Euclidean space, since the former treats time differently than the three spatial dimensions.

the axes of the two observers to be depicted this way:

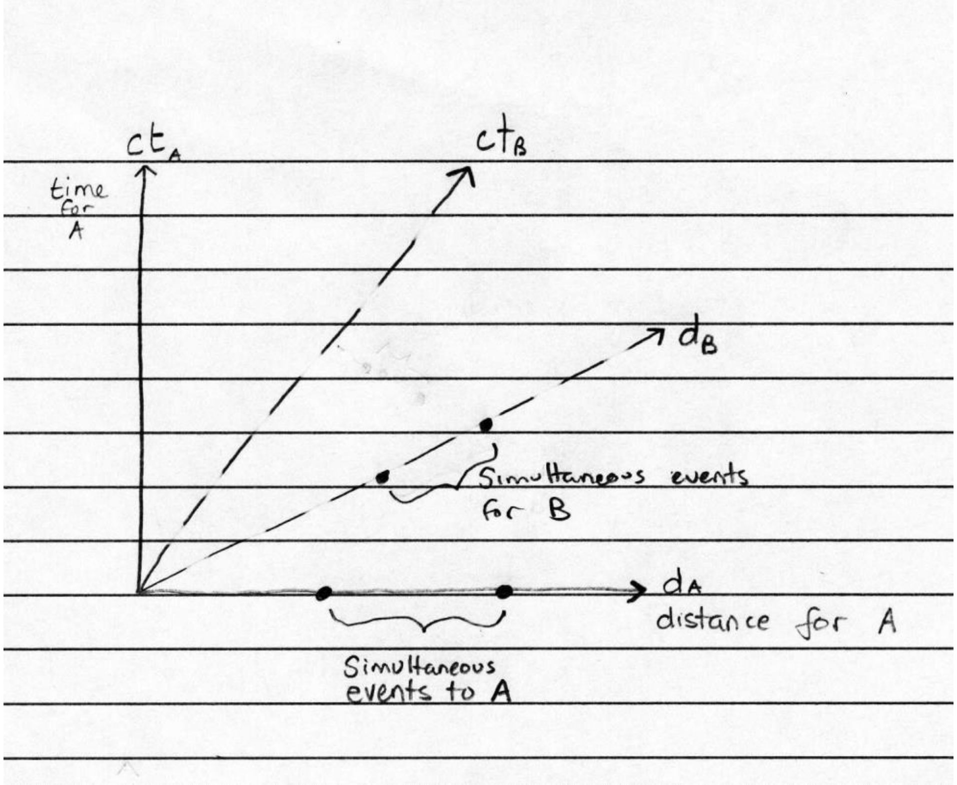

Figure 1: Understanding Simultaneity on a Spacetime Diagram

As to be expected by way of the diagram above, observer A records events as simultaneous if they fall on a line that is parallel to the horizontal axis, d_A. This is because forming this parallel line would mean that they both possess the same value on the time axis. In a similar manner, observer B will see events as simultaneous if they possess the same value along ct_B. What this implies is that observers A and B will disagree on the simultaneity of specific events. The relativity of simultaneity demonstrates that observers in spacetime will have a different set of events contained within their present moment. In Minkowski space, we may well use methods for partitioning spacetime into spaces such that we create global instants, as required by presentists. All the same, none of these partitions are sensibly to claim any fundamental status if we are to consider the totality of what is ontologically real. “Only given a matter distribution of exceptional symmetry—for example, a stream of particles all moving inertially, with zero relative velocities—would a slicing of spacetime into spaces at different times be obviously privileged,” (Saunders 2002, 281). STR produces an absolute relativity of simultaneity in which there is an infinite number of classes of simultaneity, and there is no “slice” of spacetime to define a privileged class of simultaneity to which all others can be related.

To explain how the relativity of simultaneity affects our conception of causality as well as our conceptions of past and future events, I introduce the light cone. Take a particular observer situated at the origin of some spacetime diagram for a particular instance. Instead of the format used previously, also include an axis extending into and out of the page, orthogonal to both the d_A and ct_A axes. This new axis is simply another dimension of space, so that we now have split up three dimensions of Euclidean space into two dimensions, and are therefore able to draw light cones (which are three dimensional visuals). If the observer at the origin were to turn on a light and somehow emit beams of light in all directions, then the path that this light takes would form a coned figure that extends infinitely outward from the observer. This particular cone that is formed is known as the future light cone. The reason for this name comes from the fact that within this cone are all the spacetime events the observer can reach when traveling at, or less than, the speed of light. It is safe to say that, in a similar fashion, the past light cone extends backwards in time from the origin, and it represents all the events that could be in this observer’s past. In other words, any point within or on the past light cone could send information to the observer at less than, or at exactly, the speed of light. And of course, any spacetime point will possess a past and future light cone; the spacetime point certainly need not be at the origin. Additionally, any spacetime event positioned outside the future or past light cone suggests that even if this observer were to travel forward or backward in time at the universal speed limit, *c*, he/she would still not be able to get there quick enough to causally affect that event. The following diagram is a helpful picture in understanding what light cones look like in Minkowski space.

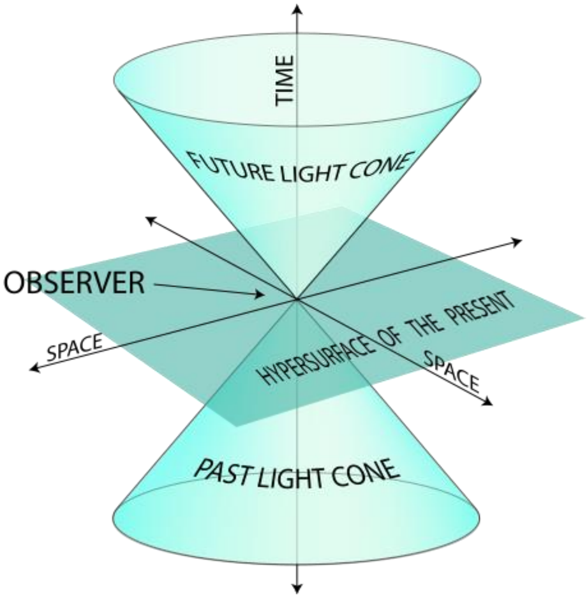

Figure 2: Light Cones in Spacetime

With this notion of light cone causality in our back pocket, I will introduce a thought experiment to demonstrate more concretely the relativity of simultaneity. Imagine three events represented on a two-dimensional spacetime diagram. The specific spacetime locations of these three events are depicted in Figure 3.

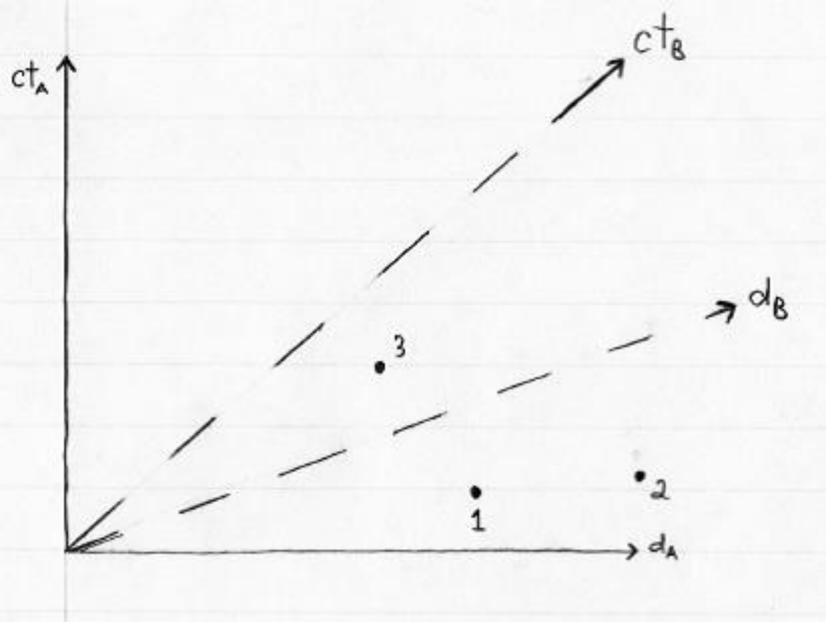

Figure 3: Locations of Events in Spacetime

Observer A, whose axes are the solid lines oriented in a typical Cartesian fashion, will report that the ordering of events is 1, 2, 3, with 1 happening first and 3 happening last. The way we calculated this temporal ordering is fairly intuitive. For each point, draw a line through it that is parallel to observer A's spatial axis, d_A. Then, for each of these drawn lines, locate the point at which this line intersects with observer A's world line, ct_A. This activity is shown below in Figure 4. Since, by construction of the diagram, one travels through time as one moves vertically up the world line, the events that intersect at the lowest point on ct_A are said to have transpired first, and the events that intersect at the highest point on ct_A are said to have transpired last. Accordingly, observer A will report that event 1 happens first, followed by event 2, and concludes with event 3.

Introducing observer B who is passing by observer A while moving at relativistic speeds, the temporal order of the asynchronous events is modified. In a similar fashion to what was done in Figure 4, the same can be done for Observer B, and in fact, I show this in Figure 5 below.

Lines are drawn through each point such that each line is parallel to d_B, which is the axis that represents simultaneous events for observer B. However, we see that event 2 intersects ct_B at the lowest point, and event 3 intersects ct_B at the highest point. Thus, observer B reports 2, 1, and 3 as the temporal order of events.

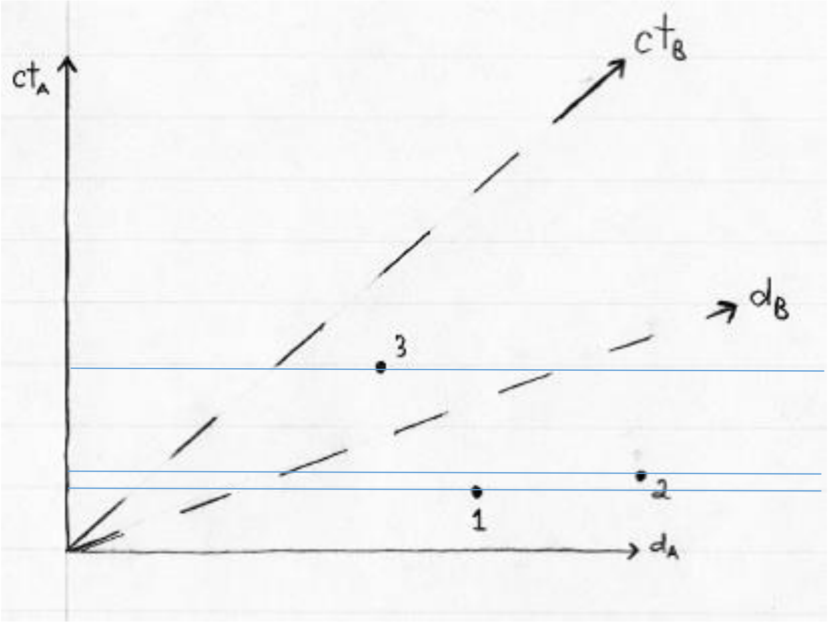

Figure 4: Ordering of Events for Observer A

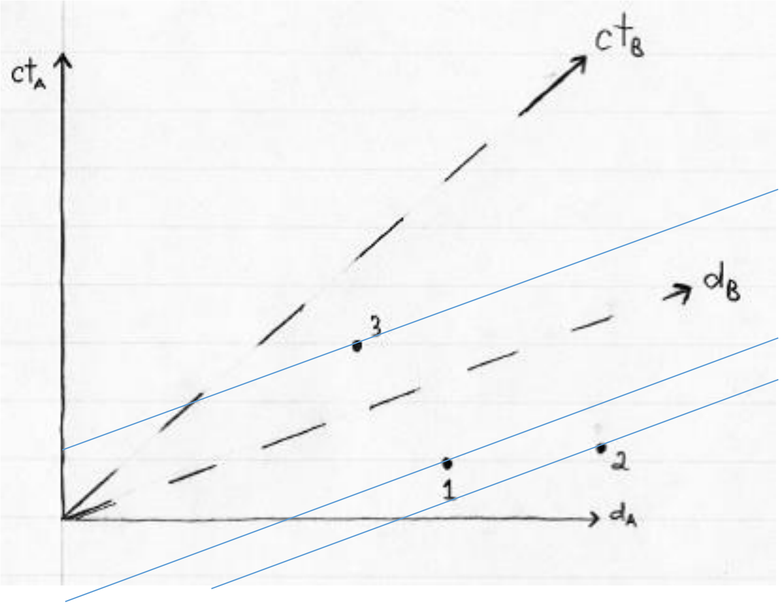

Figure 5: Ordering of Events for Observer B

Granted, both observers will agree that event 1 precedes event 3 in time. However, events 1 and 2 propose something quite interesting. Observer B will assess that event 2 occurs before event 1 has yet to transpire. Event 1 is something that is in the future for observer B when at the point in time when event 2 takes place. Meanwhile, observer A also experiences event 2, which is the exact same event 2 that observer B experiences, since event 2 is always in the same point in spacetime. Nonetheless, event 1, in the eyes of observer A, is a distant memory when he/she is experiencing event 2. Essentially, both parties experience event 2, but when observer A does so, event 1 has already passed. Yet when observer B does so, event 1 has yet to transpire. Without picking a particular reference frame, event 1 is both in the future and in the past.

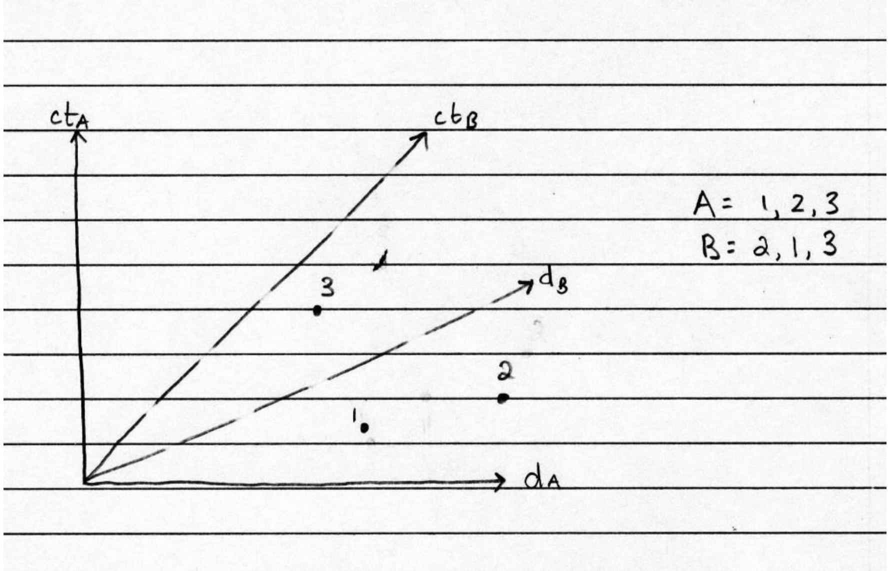

Figure 6: Summary of the Differing Order of Events

The reason that both parties are able to agree on the temporal order between events 1 and 3 is because event 1, in all frames of reference, falls in event 3's past cone, while event 3 always falls in event 1's future cone. The disagreement of temporal ordering between events 1 and 2 occurs because these spacetime events do not fall into each other's light cones. They have no universally agreed upon temporal order because they do not have the past-future relationship that light cones prescribe. Observer B would be forced to tell observer A that he/she went back in time by travelling faster than the speed of light. Of course, physics now dictates that nothing can move faster than the speed of light, and thus the temporal ordering of events outside of a particular point's light cone is bound to create some headaches. So, light cones that are drawn in Minkowski space partition the universe into five topologically connected sets: the events within the future light cone, the events on the future light cone, the events within the past light, the events on the past light cone, and events outside the light cones. The most interesting of these sets is the last one. Events that lie outside the light cones are known as *space-like* events. Events with space-like intervals imply that $|c\Delta t| < |\Delta x|$. Furthermore, for space-like events, the invariant relativistic interval,

$$(\Delta s)^2 = c^2\Delta t^2 - (\Delta x^2 + \Delta y^2 + \Delta z^2)$$

is imaginary. Space-like events are so far apart that each event cannot have a causal relationship with the other. Nothing from event X can affect event Y if events X and Y are space-like separated. While they may be widely unnoticed and not influential in our daily experience of life, space-like events do exist, and they not only show the nonexistence of simultaneity as a real physical relation among events, but they also show that temporal order, as a real physical relation among events, does not exist objectively. As a matter of physical principle, no frame of reference is preferred over another. Although employing certain reference frames over other ones can make sense and be practical in certain situations, there is nothing physically illegal about using another reference frame that contradicts the simultaneity of events in question. In fact, saying that certain events have or have not transpired is a relative statement.

Nonetheless, it is important to note that STR does not invoke a violation of the principle of causation wherein every effect has some cause that precedes it. Even though one event can be said to be either before or after another event, we know that these two events have no causal relationship. Two events that are perceived to have different temporal orders between observers must be space-like, and they do not allow any information to be sent between them.

Chapter 5

Quality of Realness

The issue that numerous competing theories of time deal with is the realness of different temporal categories. Whereas eternalism deems that all points of time, be it past, present, or future, are equally real, presentism states that only that which occurs in the present is real. Of course, this whole debate is rendered moot without a working definition of what is real.[10] It is quite evident that despite their disagreement on *what* is real, eternalist and presentists alike both agree that two states of being exist: real and unreal. Thus, realness can be thought of as a unique property that a particular event can possess. If we can establish specific features of an event to serve as the minimal criteria for realness, then it can be said that any event that holds these properties is *real*. Moreover, if we think of realness as a value that an event can possess, then we can essentially establish a binary system. An event can either possess realness or possess unrealness—two values are available. It can be argued that there are other values within the

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[10] In fact, John D. Norton, a philosopher of science at the University of Pittsburgh, dismisses the entirety of the eternalist versus presentist debate because he sees it merely as a disagreement of definitions. He writes, "When a presentist asserts the unreality of past and future events, in just which way are they unreal or ersatz? It cannot merely be that they are not present. For that makes the presentist's view true by definition," (Norton 2015, 104). Norton contends that both sides agree entirely with STR, and so "they will disagree, however, just on one simple issue. How the label "real" should be applied. The whole debate reduces to a difference on how to assign a label," (Norton 2015, 104). I agree that the argument at hand boils down to defining labels, but I do not share Norton's lack of interest in this debate. I think that what we humans consider to be real has meaningful implications.

range of the “reality function,” but this possibility unnecessarily complicates the discussion. For the matters at stake in this philosophical discussion, it is sufficient to claim that an event is either real or unreal, and cannot be *somewhat* real. With this, it is straightforward to assume than an event in spacetime can only have one realness value (McTaggart and Broad 1921). That is, an event cannot possess both realness and unrealness. This follows from basic logic, which states that propositions *p* and ¬*p* cannot both be true. An event is either real, or it is not. And so, when we speak of two events sharing the same realness value, we are not, as one may think, speaking to whether or not these events are real. If two events share the same realness value, they are either equally real or equally unreal. Likewise, if we can claim that two events have different realness values, then we know that one event is real while the other is not. However, in this second case, we have not yet prescribed a way to figure out which is real and which is unreal.

The quality of realness is easier to understand if we denote “shares the same realness value” by “R” such that “aRb” denotes that “a shares the same realness value as b.” Then, R can be said to be an equivalence relation. Accordingly, let R be a binary relation on the set of all spacetime events such that it is reflexive, symmetric, and transitive. If one can accept that R is an equivalence relation, we have the following properties:

- *a*R*a* for all *a*
- *a*R*b* if and only if *b*R*a* for all *a*,*b*
- if *a*R*b* and *b*R*c*, then *a*R*c* for all *a*,*b*,*c*

This first property summarizes the reflexivity of the equivalence relation by simply asserting that spacetime event *a* shares the same state of realness as the same event *a*. The second bullet point states the abelian, or commutative, nature of R by saying that if *a* is just as real as *b*, then *b* is just as real as *a*. These two postulates are fairly intuitive. The next property, that of transitivity, on the other hand, is much more telling in the debate against the presentists. It states that if *a* is just as real as *b* and *b* is just as real as *c*, then *a* is just as real as *c*.

So far, we have not delineated what it means to be real. All we have done is create a dichotomy between the states of realness and unrealness, as well as describe the properties that exist between two or more events that share a realness value. Fortunately, this description of the quality of realness will be adequate to mount a meaningful attack on the presentist's claim. The following example is directly taken from Daniel Peterson and Michael Silberstein's "Relativity of Simultaneity and Eternalism: In Defense of Blockworld," as their example succinctly uses the transitivity of realness to argue in favor of eternalism (Peterson and Silberstein 2010). It should also be noted that Peterson and Silberstein's example is a minor variation of the classic Rietdijk-Putnam argument (Rietdijk 1966). Consider Figure 7 below.

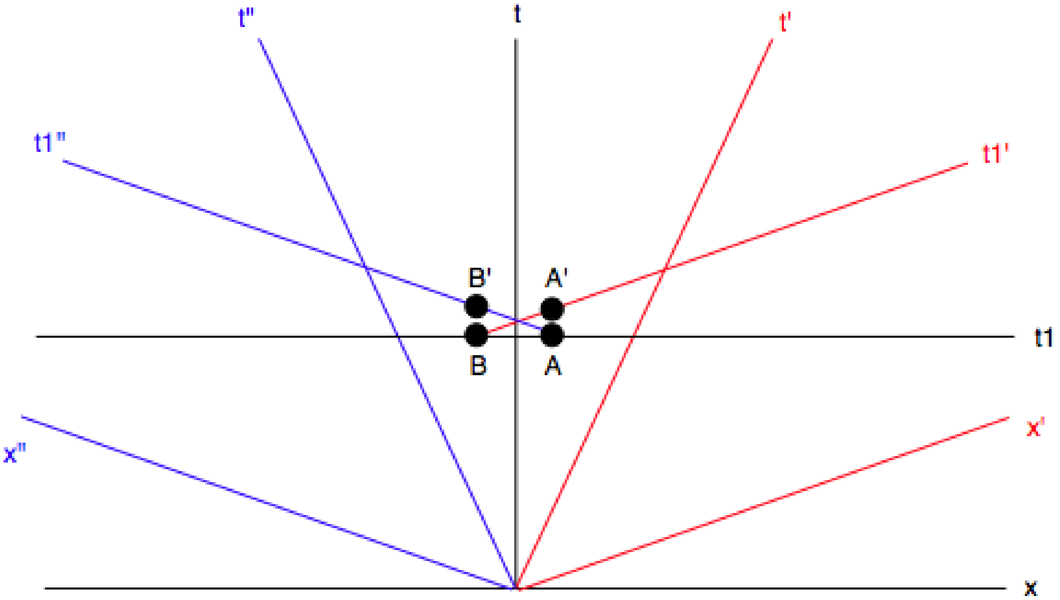

Figure 7: Transitivity of Realness Example

Consider the *x* and *t* axes to be your spatial and temporal dimensions, respectively, while you are at rest in your living room. Event A represents your friend Alice stubbing her toe, while event B represents your friend Bob stubbing his toe. From your frame of reference, these events happen simultaneously, and this is displayed in the figure by way of the fact that they possess the same value on the *t* axis. Now, events A’ and B’ represent Alice and Bo screaming in pain from their prior stubbing. Again, still from your frame of reference, events A’ and B’ are simultaneous, though they occur later in time relative to events A and B. Naturally, as is expected with any physics thought experiment, allow two extraterrestrial spaceships to fly above your living room at relativistic speeds. The primed spatial and temporal axes in red refer to the first spaceship, while the double primed axes in blue refer to the second spaceship. From your perspective, we have a clear picture of what is going on. Alice and Bob stub their toes at the same time, and then later in time, Alice and Bob simultaneously cry in agony from having stubbed their toes. The reference frames for each of the spaceships denote a differing ordering of circumstances. As we saw previously with Figure 5, the red line going through events A’ and B explains how the primed spaceship will conclude that events A’ and B are simultaneous. Similarly, the double primed spaceship will conclude that events A and B’ occurred simultaneously. More explicitly stated, one spaceship believes that Alice stubbing her toe and Bob screaming are simultaneous events, and the other ship gathers that Bob stubbing his toe and Alice screaming occur simultaneously.

If two events are simultaneous, then they can be said to share the same realness value. For if simultaneity is not the measure by which we denote an ontologically unique status with respect to temporal conditions, then seemingly nothing can be used as a criterion (Rietdijk 1976). With these relations of simultaneity established, let us treat the conclusions of each observer as equally valid. From your frame of reference, we have

$$ARB$$

and from the spaceship with the primed axes, we have

(A')R(B)

Lastly, from the spaceship with the double primed axes, we have

(A)R(B')

Since A shares the same realness value as B, and B shares the same realness value as A', by the transitivity of the R relation, we can conclude that (A)R(A').[11] In the same manner, we can use the transitivity of the propositions above to conclude that (B)R(B'). As a result, we can conclude that a prior event, that of Alice stubbing her toe, shares the same realness value as a later event, which is of Alice screaming from stubbing her toe. Take your frame of reference in which A and B occur simultaneously while A' and B' occur simultaneously at a later point in time. If we wish to say that Alice stubbing her toe occurs in the present, then Alice screaming occurs in the future, and so the present and future share the same realness value. Furthermore, if Alice screaming occurs in the present, then Alice stubbing her toe occurred in the past, and so events in the present and past share the same realness value. Lastly, let A occur in the past and A' in the future (implying that the present takes place in the time between the stubbing and the screaming). Then, we can conclude that the past and the future share the same realness value. IN any of these cases, we have openly contradicted the presentist's claim that only that which occurs in the present is real. We have also raised suspicions about the growing block universe view, since we have shown that future events share the same quality of realness as both past and present events. In fact, we have shown that, since one's perception is no more indicative of ontological realness

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[11] We know that B shares the same realness value as A' because, as stated, A' shares the same realness as B. Thus, we simply apply the abelian nature of the equivalence relation R.

than another’s perception, all events, regardless of their temporal association, share the same realness value.

Nonetheless, it must be made clear that we have not shown that all events are real; we have simply shown that all events share the same realness value. It is possible that this realness value that is continuously mentioned is, in fact, the quality of unrealness. Thus, we can say that either all events are real or all events are unreal since they must share the same value. This distinction, at its core, basically asks whether or not one wants to say that anything exists at all. We are left with the choice of accepting that everything is real, regardless of temporal location, or that everything is unreal. There are ontological skeptics who believe that nothing, even time, exists, but this is considered to be an extreme and isolated point of view. British physicist Julian Barbour has recently gathered a great deal of publicity for his advancement of a timeless physics. He contends that time is merely an illusion with no physical hold in existence. He engages Einstein’s theories of relativity by considering all the possible qualitative shapes that can be generated by matter, and he ultimately concludes that these theories can be completely understood without the introduction of the dimension of time. In essence, if the theories of relativity can be understood without time, and we know that time is something experienced differently depending upon the individual, then perhaps the dismissal of time, and its classification as an illusion, is not a completely out of the box idea. Wile he acknowledges that “the block universe picture is in fact close to [his] own [conception of the universe],” Barbour goes even further by dismissing not only the passage of time (as eternalists do),but the existence of time as a dimension altogether (Barbour 2000, 143). Timeless physics is a controversial way of interpreting modern physical theories, and various physicists, including Lee Smolin and Sean Carroll, have criticized it (Carroll 2010). I do not wish to endorse Barbour’s views, but I introduce them to show that if physicists are willing to go as far as to say that time itself does not exist, then surely it is less tendentious to support a block universe than what may have been originally thought. So by taking a slight leap of faith that there is one event in time that is real in the universe, we are forced to conclude that all events share the same realness value and are thus, real.[12] This slightly amended account of the Rietdijk-Putnam narrative illustrates that by a basic notion of realness, use of Minkowski space diagrams, and the idea that no observer is preferred above another, we can confidently defend the eternalist view of a blockworld.

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[12] American theoretical physicist Lee Smolin cleverly remarks that in order to become an eternalist, one only need accept STR and the notion that just the present is real. He writes, "What's powerful about this block-universe argument is that to entertain it you need only believe that the present is real; the argument [of the relativity of simultaneity] then forces you to believe that the future and the past are as real as the present. But if there *is* no distinction between present, past, and future—if the formation of the Earth or the birth of my great great great granddaughter are as reals as the moment in which I write these words—then the present has no special claim to reality, and all that's real is the whole history of the universe," (Smolin 2013, 63).

Chapter 6

Why You Should Not Want To Defend Presentism

Now when thinking about time from an ontological and metaphysical perspective, the notion of presentism seems to stand on rather shaky ground. Presentists hold that only that which is present exists. In other words, if one were to make an accurate list of all the things in the universe that exist, there would not be a single 'non-present' object on that list. But as explicitly described previously, what is present is not agreed upon, and my present may be vastly different from your notion of present when it comes to space-like events. A presentist is thus proposing that what exists is subjective and dependent upon the individual. It seems unlikely that what is "real" should depend on subjective human experience. A large portion of history has shown us that just because something may be revealed to humans in a certain manner, it is not necessarily true. For example, we experience the earth as flat, and we experience speeds as following Galilean relativity when considering multiple coordinate systems. And yet, we know that these initial intuitions are erroneous. Reality should be concrete and objective, for a physical world would certainly exist without the experience of the individual to examine it. By using only our sense perception to interpret information around us, we are merely experiencing phenomena of the senses rather than experiencing *noumena*, or things as they are in themselves (Kant and Meiklejohn 2004). The human perspective is *our* perspective on the universe, but science has shown us that in reality, fundamental and universal laws exists that may be contrary to our cognitive perception. The notions of past and present are based on the experience of the individual, and without the individual, there is no way to claim that there is a past, present, or future. All points in time could be just as real as the next when humans are taken out of the equation. The eternalist philosophy of time accepts this and makes a distinction between the temporal and the ontological status of objects. Eternalists admit that in a particular temporal location, it is true that no non-present event can exist right then and there for said individual. But in the ontological sense, they will claim that a non-present object can be in the domain of the set of existing events. The individual simply does not have access to some of these existing events because of their particular orientation in spacetime. In other words, temporal location does not matter at all when it comes to questions of ontology. And why would it? Should *spatial* location matter when it comes to ontology? Most would agree that where an object is located spatially does not affect its capacity to exist, or to be (Sklar 1974). It is irrelevant whether an event is to my right or to my left; it exists regardless of its relative spatial orientation.[13] Likewise, where an object is located temporally does not affect its capacity to exist. It is irrelevant whether an event is in my past, present, or future because to another observer, it could be in either of the two temporal divisions that do not hold true for my frame of reference. Since I hold no more authority than the next observer in determining whether a spacetime event exists in reality, it is only fair to say that all events must exist. C.W. Rietdijk, a 20th century theoretical physicist, wrote in response to presentists,

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[13] American philosopher at the University of Michigan, Lawrence Sklar, writes that “to deny existence to entities because they fail to exist at the moment of assertion is as silly as to deny objects existence because they fail to exist at the *place* at which the assertion is being made. We should no more deny *reality* to the “then but not now” than we would to the “there but not here.” And similarly for the future happenings. They are as determinately real as present and past happenings, and to deny this would be as pointless as to deny determinate reality to events on our left, but admit it for events where we are and on our right,” (Sklar 1974, 273).

> “A proof is given that there does not exist an event, that is not already in the past for some possible distant observer at the (our) moment that the latter is “now” for us. Such event is as “legally” past for that distant observer as is the moment five minutes ago on the sun for us (irrespective of the circumstance that the light of the sun cannot reach us in a period of five minutes). Only an extreme positivism: “that which cannot yet be observed does not yet exist,” can possibly withstand the conclusion concerned. Therefore, there is determinism, also in micro-physics,” (Rietdijk 1966, 341).

If you accept the assumptions of STR, the theoretical implications derived from these assumptions, and the fact that STR makes concrete claims about the reality of the universe, then you are forced to accept the disappearance of the passage of time, as we know it, from physics. As an epistemological tool, science is the manifestation of operationalism. Einstein asserts that the only meaningful way to define a quantity like time is to stipulate how to measure it (Einstein 1961).[14] With this, a scientist should not ask what is real, but rather what it is that an observer can observe. The next step is to inquire as to whether different observers will agree or disagree

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[14] While Einstein expressed his subjective idealist views when developing his theories of relativity, he, in his later years, regretted his operationalism. In Karl Popper’s autobiography, Popper discusses how Einstein told him in 1950 that understanding simultaneity in positivist operational terms was a “mistake” (Popper 1976, 97). Nevertheless, while it is interesting to note Einstein’s change in philosophical sentiment, I am obliged to follow his operationalist views as presented when he formally published his theories, rather than his feeling when talking to a colleague in his elder years. For all we know, perhaps Einstein’s recognition of his “mistake” was itself a confused mistake stemming from his being at the end of his life. In any case, we should follow his physics.

about what they are observing. Reality does exist for operationalists, but the way to uncover this reality is by way of what is observed. To determine if something is objectively true is to determine if all observers will agree on it. In Einstein's STR, the relativity of simultaneity shatters any notion of absolute time, and there is no reason for observers to agree about the order of events that do not share a causal relationship. There can be nothing real about simultaneity or "now." What we take from this is a reformulated view of the universe, one in which there is no reference to what time it is now or to anything corresponding to our experience of the present moment. Because it holds for all events and for all observers, the only thing we can conclude of physical reality is its causal structure. As Leibniz contended, causal relationships are the only reality that resemble time (Grosholz 2015). With a universe in which time does not flow, the history of the cosmos can be seen as one reality, a block that is rigid and unchanging. Twentieth century mathematician Hermann Weyl writes, "The objective world simply is, it does not happen. Only to the gaze of my consciousness…does a section of the world come to life as a fleeting image in space which continuously changes in time," (Weyl 1949, 116).[15] Special relativity is simply incompatible with presentism.

The relativity of simultaneity is not a controversial idea. Any physicist with an understanding of STR is aware that observers traveling relative to each other will assess certain

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[15] Einstein writes something similar to what Weyl has said here. When a good friend and colleague of his, Jewish Italian engineer Michele Besso, passed away, Einstein wrote a letter of condolence to Besso's family. Einstein wrote, "Now he [Besso] has departed from this strange world a little ahead of me. That means nothing. People like us, who believe in physics, know that the distinction between past, present and future is only a stubbornly persistent illusion," (Einstein and Calaprice 2013, 113). Einstein died that same year. The number of physicists who take sentimental comfort in the block universe view is strikingly high.

events to have different temporal orders. The issue that STR raises involves the ontological status of present and non-present events. Presentists tend to hold their view on the basis that the present must have some special ontological significance. This idea does, in fact, appear intuitive. The present is the infinitesimally small moment that separates what has become and what has yet to become, and it is thus some grand divider between what is real and what is not real. This is a fair statement to make at the level of the individual. In fact, even a hardline determinist like Einstein understood the significance of the human experience of the now.[16] A plane of simultaneity exists for an observer at every spacetime point, and this plane helps to shape the way people interpret the environment around them. So the present exists in the same way that the feeling of a flat earth exists as an actual experience that humans have. Nonetheless, there are an

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[16] In Vienna Circle philosopher Rudolf Carnap's intellectual autobiography, Carnap describes the anguish that Einstein suffered because of the disconnect between his physical theories and his phenomenological experience. "Einstein said that the problem of the Now worried him seriously. He explained that the experience of the Now means something special for man,…but that this important difference [between the present and the past or future] does not and cannot occur within physics…I remarked that all that occurs objectively can be described in science; on the one hand the temporal sequence of events is described in physics; and, on the other hand, the peculiarities of man's experience with respect to time,…can be described and explained in psychology…We both agreed that this was not a question of a defect for which science could be blamed…Since science in principle can say all that can be said, there is no unanswerable question left. But though there is no theoretical question left, there is still the common human emotional experience, which is sometimes disturbing for special psychological reasons," (Carnap 1963, 37-38). These intellectual giants of the 20th century did not wish to ignore or discount human beings' experience of the passage of time. Rather, they wished to illuminate the reality of our experience and explain, in objective terms, how each individual's perception of the world is but one take of the infinite number of possibilities into which spacetime can be sliced.

infinite number of planes of simultaneity passing through any given spacetime point.[17] Other than categorizing these planes based upon which observer they happen to fit, there is no physical test to distinguish one plane from another. So while to the satisfaction of the presentists, there is some special status given to the present, this present has no unique ontological status in the grand frame of the universe. To think that *your* particular plane of simultaneity is any more relevant than the next is a rather narcissistic viewpoint. It is comparable to claiming that the acceleration of a free-falling body due to the force of gravity is definitively 9.8 m/s^2. Physicists of course agree that this is true only for a free falling body near earth. The acceleration of a body in free fall caused solely by gravity is not a fundamental quality; it is contingent upon the masses and distance between the bodies in question. The quality of being present is similar to the acceleration of a body in free fall. It is not universal because it is dependent on certain variables, and as such, its contingency on external factors precludes it as a fundamental condition. It follows that something that is not fundamental cannot be the standard by which to judge ontological status. Any ontological differences within the dimension of time should intuitively be observer independent. In the context of Minkowski space, the only observer-independent elements are the light cone structure of spacetime events. Phenomenology may define a concrete notion of the present, but the ontology that relativity provides cannot. In the view of STR, events do not take place. Rather, events merely exist in a certain orientation within the fabric of

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[17] The most intuitive way to define a plane of simultaneity is by classifying all the spacetime points which have the same value on the world line axis as the point in question. This is the interpretation given in Figure 2. A more sophisticated way to interpret a plane of simultaneity at a point is to group together all the space-like events relative to the point in question. Either way, while this subtle distinction is interesting to ponder, it has no noticeable effect on the argument at hand, and so I assume the first convention out of convenience's sake.

spacetime, and observers assess these events to be situated in some temporal order depending upon the manner in which the observers travel through this spacetime continuum.

Chapter 7

General Relativity and Current Theories

Thus far, we have observed a trend of the dissolving of a concrete objective view of time. We started with Aristotle's absolute time and absolute rest frame. Then, Newton shocked the world with his *Principia* that kept the notion of absolute time but eliminated of the existence of an absolute rest frame. As discussed, Einstein's STR describes a universe wherein there is no absolute time or absolute rest frame, but rather there is only observer-dependent time. Only space-time intervals are absolute. One may wonder whether or not the general theory of relativity reverses this trend and presents an understanding of time that inches closer to what Aristotle or Newton thought. Nonetheless, this does not appear to be the case. While STR abolishes absolute time, the law of universal gravitation seems to, in fact, require this notion of absolute time. When two bodies experience a force that is inversely proportional to the square of the distance between them, this distance must seemingly be determined at a particular instant in absolute time. Without going into great detail, Einstein resolved this quandary by employing a spacetime geometry that is curved, unlike Minkowski space. This curvature relates to the strength of gravity that is present there. In other words, gravity is simply a manifestation of the spacetime geometry that permeates the universe. While in STR, spacetime played a passive role, general relativity allows spacetime to act on matter and matter to act on spacetime. In reference to the idea that bodies must follow the geodesics outlined by a curved spacetime, Penn State theoretical physicist Abhay Ashtekar writes that, "as a consequence of this paradigm shift, time in general relativity is less rigid, more 'elastic', than that even in special relativity," (Ashtekar 2015, 71).

So while special relativity demonstrates that time intervals between events depend on the state of motion of the observers who measure them, general relativity further expounds that these time intervals also depend on the location of the observers. Thus, physics has developed in such a way that each new theory portrays a less rigid, less absolute, and more elastic notion of time. Of course, physics does not end with general relativity. Specifically, since large-scale homogeneity and isotropy of space has been observed to a high degree of accuracy, Einstein's equations imply that the expanding universe must have emerged from a singularity at a particular time in the past. However, the Big Bang is supposed to have created the very spacetime geometry that allows us to even speak of time intervals. Thus, thinking about what happened *before* the Big Band is an incoherent question within the context of general relativity. In other words, singularities such as the Big Bang are predications of general relativity in a domain in which the theory is simply invalid.

In particular, the current theory of loop quantum cosmology suggests that it is possible that quantum evolution never breaks down as one moves closer to the singularity. As Ashtekar writes, "the quantum state never encounters infinities; none of the physical observables ever become singular. In this sense, then, time does *not* have a finite beginning in loop quantum cosmology," (Ashtekar 2015, 72). Nonetheless, there are other interpretations of loop quantum cosmology, which Ashtekar recognizes as well, that could present a universe that does have a finite beginning. The former interpretation of loop quantum cosmology is favorable to the block universe view, and the latter interpretation lends credence to absolute time (and thus is favorable to the presentist's view). Regardless, my point in introducing this section is to show that current theories *do* allow for the block universe view, in which time is not absolute and is merely based on human perception. I am by no means attempting to make claims about current theories in physics that the greatest scientific minds of today are still developing; I simply want to argue that the current theories in development certainly do *not* contradict or repudiate what I have said thus far. In summation, when one utilizes special or general relativity to understand time, it becomes obvious that absolute time, and thus an absolute understanding of the present, does not hold any ground. Furthermore, as one looks to the most cutting-edge theories of 21st century physics, the possibility to continue this block universe view endures. Of course, it still remains a mystery as to what these ultramodern theories will ultimately conclude.

Chapter 8

Causality and Determinism

Within the block universe interpretation of STR, the notions “past,” “present,” and “future” seemingly lose their meaning. This is because using only one’s own individual frame of reference as a tool for understanding the fundamental nature of the universe, without recognizing the frames of references of other observers, seems foolish. For example, different observers may contain different events in their list of past events, and so the term “past” is not a well-defined set of events that is agreed upon by all observers. Nonetheless, within the block universe theory, the causal structure remains. So when philosophers like John Randolph Lucas write, “The block universe gives a deeply inadequate view of time. It fails to account for the passage of time, the pre-eminence of the present, the directedness of time and the differences between the future and the past,” I am puzzled (Lucas, 1989, 8). I do not think that the block universe fails to account for the passage of time. In the block universe, all observers agree on the order of causally related events, though they need not agree on the order of space-like events. Yet the block universe does recognize the sequence of time since it requires that all observers agree upon the causal relationship between two events. Take two events, A and B. Event A is either a cause of B, B is a cause of A, or neither is the cause of the other. All observers will agree upon which of these tree options events A and B satisfy. It is important to note that the block universe does not imply that the terms “before” and “after” are useless. Again, these terms are necessary when it comes to the causal relationship of events. If event A is the cause of B, then event A must be said to have transpired *before* event B. This fact is fundamentally real since it is agreed upon by all observers. However, according to the block universe, saying that event B is happening “now” is an issue of perspective rather than being an inherent quality of the universe. There is no preferred moment in time, but that is not to say that an ordering in time does not exist. Therefore, Lucas' criticism of the block universe theory is countered by the fact that the block universe assumes the causal structure of the universe. The block universe essentially claims that events do cause one another and time does have a well-defined order, but where we are in that progression of causality is not well defined. All observer-independent information is captured by the causal structure of the universe, and that is precisely what we mean when we talk about the passage of time.

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