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Models of Time Travel and their Consequences

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Cover Page Footnote

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"How wonderful that we have met with a paradox. Now we have some hope of making progress."
Neils Bohr

Defining Time and Einstein's Universe

Introduction

This is not an attempt to prove that time travel is possible. Rather, I am going to start with the assumption that time travel is possible under certain conditions of relativity that will be outlined, and then proceed to argue for three possible models of time. I will then outline a list of experiments that would either lend credibility to, or discredit, the three models.

The reader might question, "Why three models?" As will be seen, these are the only three logically sound, or realistically possible, models that can exist under my assumptions. I fully invite any reader to provide another rational model under the same conditions I have assumed.[1] Lastly, this work is intended to be for a general audience just as much as it is intended for the reader who has studied the topic before.

Definitions, Definitions, Definitions

Like many other works about time, this will also begin with the obligatory section on "what do you mean when you say 'time travel.'" Putting a direct definition on time has been a struggle for physicists and philosophers for quite a long while now. Many people in the science community are happy to say that time is a useful mathematical tool as a fourth dimension, and mankind has been measuring time throughout the majority of recorded history, but how can we measure something that we cannot touch, or feel, or smell, or taste?

[1] In fact, if the reader is successful in this, please make an attempt to contact me.

The way of looking at time that lasted for the longest period was Isaac Newton's definition (1687). He made a distinction between two different types of time: absolute time and relative time. The first was absolute time. Absolute time existed without regard to man or the universe and flowed independent of space or motion – as physicist Michio Kaku once called it, "God's wristwatch." Newton's second type of time was called relative time. Although it has nothing to do with Einstein's relativity, Netwon's relative time was the quantifiable time and was only measured by the duration of motion of objects. Newton's definition of time was accepted as the outright definition by the world at large, that is until Einstein redefined how we pictured time in 1905. Einstein not only suggested that observers traveling at different speeds recorded different lengths of time between the same two events, but he also argued that space and time were connected – the exact opposite of Newton's first definition.

It is under Einstein's relativistic world where we will begin.

Einstein's Realization that Time and Space are Related

The story says that Einstein was riding on a trolley-car in Bern, Switzerland and watching the clocktower as he was riding away from it. He started to think what he would see on the face of the clock if he were suddenly propelled away from it at the speed of light. He concluded that he would follow along with the photons that bounced off the face of the clock, since they too travel at the speed of light, and that he would never witness the hands tick. In a sense, traveling at the speed of light, an observer would observe time to stand still.

However, imagine that you are floating still in the dead of space. You are obviously not moving through any spatial coordinates, but what you are doing is solely traveling through time. This is what mathematicians and physicists mean when they refer to time as a fourth dimension.

Taking these two circumstances into consideration, we have a decent picture of how space and time are related in Einstein's universe. That is, one has the option of not traveling through space but traveling one hundred percent through time, but as one starts to move faster and faster (approaching speeds up to the speed of light), one starts to move less and less through time and only through space. In this respect, if you would like to measure a longer amount of time between two events than someone who is sitting down, simply go for a walk.

Another important aspect of Einstein's universe is the disproof of simultaneity. The situation, well known to students of relativity, has one observer sitting on a train that is moving close to the speed of light and a second observer sitting stationary on the outside of the tracks. At the moment the midpoint of the train passes by the stationary observer, miraculously both ends of the train are struck by two different lightning bolts. The stationary observer says that both ends of the train were struck at the same time, or that there was a time difference between the two events of zero. However, the conductor on the train, since the train is headed in one direction (toward the light in the front and away from the light in the back), sees the light from the front end first, and then sees the light from the second end, i.e. the observer on the train says that the front end of the train was struck first, then the back end, or that there is a time difference. Through this story, Einstein shows that there cannot be anything described as "simultaneous" because observers traveling at different speeds will measure different lengths of time occurring between different events.[2]

Speed is not the only thing that affects space and time in Einstein's universe. Mass as well can warp the two. This was demonstrated experimentally when it was confirmed that large objects,

[2] The role of light and some other consequences of Einstein's universe that specifically relate to this can be found in Mook, Delo. Vargish, Thomas. "Special Theory of Relativity." In *Inside Relativity*, 85 – 95. Princeton, New Jersey: Princeton University Press, 1987.

such as the sun, could deflect starlight. In fact, all objects within a gravitational field are subject to "artificial" fields of curved space-time.[3]

So, in Einstein's universe, just as you would measure longer time between two events taking a walk than you would sitting down, you would also measure longer time closer to a large mass. This has been experimentally shown by putting identical clocks on the surface of the earth and on a plane that flies around the world – indeed it was shown that the clocks showed different times. Even clocks on GPS satellites are calibrated to run at about 7 microseconds faster than clocks on the surface of Earth to account for relativistic time dilation.[4]

Time as a River

One of the largest assumptions that I am going to make is that time functions like a river, with all points moving forward together simultaneously. The points in time are not necessarily moving forward at the same speed, but what I want to point out is that there is a specific direction.[5] To argue for this, I will invoke our shared experience as human beings. We have always observed time to travel from the past to present and this is what I will refer to as time's distinct direction – I will refer to this as "forward" in time.

The reader might be inclined to ask questions like "How wide is the river?" or "What is the source of the river?" But these questions are taking the metaphor too literally and running with it. The point of the river analogy is to illustrate that time has a direction and appears to flow. How I want to think of time, then, is as a string of (possibly) infinite "presents" that are all moving forward together.

[3] Gibilisco, Stan. "The Principle of Equivalence" In *Understanding Einstein's Theories of Relativity*, 142 – 153. New York, New York: Dover Publications Inc, 1983.

[4] Pogge, Richard. "Real-World Relativity: the GPS Navigation System." Astronomy Ohio State. April 10, 2014. Accessed April 12, 2015. http://www.astronomy.ohio-state.edu/~pogge/Ast162/Unit5/gps.html.

[5] For a detailed article providing evidence to argue this claim, see "On Time Travel" by John Cramer.

Words of Warning

Henceforth, we can consider any time travel forward in time as being plucked from a certain point in the river, letting that time carry on, and being placed back in at a later point. Instantaneous time travel forward in time creates some issues that I will get into later. Travel into the past, then, can be considered as the ability to travel backward in our river. This is where things get more complicated. Where in travel to the future we can easily imagine ourselves being "removed from time" and being placed back in at a later point, travel into the past brings up issues such as the famous grandfather paradox.[6] The conclusion to this apparent paradox will be an important differentiation between two of the proposed models of time. To put it another way, the question of whether or not a traveler to the past can kill his or her grandfather has a binary answer: yes or no. Again, this will be an important distinction in definitions to come.

A Brief Note on the Present

Understanding what "now" means can be difficult. If time is a continuum that matter moves through from the past into the future, then "the present" is a term that has little meaning because that singular point in time is perpetually at a different place. If, however, as some scientists are inclined to believe, time is quantized, "now" has a different meaning. If time is quantized, then that means that time moves forward in distinct undividable increments – this unit has been

[6] In case you are unfamiliar with the idea, the grandfather paradox was first posited by Nat Schachner in the short story *Ancestral Voices* (1933). It says that if you were able to go back in time and then killed your grandfather, you would never then be born. On the flipside, if you are never to be born, then it is impossible for you to go back in time and kill your grandfather.

labeled a chronon. There is a sizeable amount of research going on today to discover the nature of the present, as we shall see.

On the Nature of the Machine

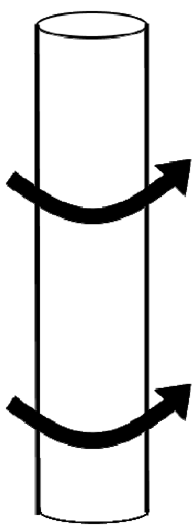

Figure 1

In 1974 physicist Frank Tipler showed that a solution to the equations of general relativity could be found in an infinitely long cylinder that was spinning about its central axis. He showed that observers traveling at sub-light speeds near the cylinder could end up traveling back in time (See Figure 1).

Now, the full description of how Tipler came to this conclusion can be explained using Minkowski "light-cone" diagrams. These will be explained in a moment, but here I want to talk about how the method of traveling through time effects our understanding of what it means to "travel through time."[7]

Like in the Tipler Cylinder, the most realistic models of time travel will likely involve the warping of space-time. One possibility of achieving time travel is often characterized as a large ring made of an incredibly dense material – so dense, in fact, that it has the ability to warp space-time around the traveler within the ring.

A third theorized machine, or method, of traveling through time would be traveling through a wormhole. Einstein and Rosen proposed that wormholes could exist that functioned as links between two otherwise inaccessible parts of the universe. In this model, two "throats" of two

[7] For a detailed description of Tipler Cylinders and how they are explained by Minkowski diagrams, I recommend Nahin, Paul. "Tipler's Time Machine." In *Time Machines*, 92 – 95. Springer-Verlag, New York: Springer-Verlag New York Inc, 1999.

wormholes meet at two oppositely charged elementary particles, and this warps space-time.[8] There is still much not understood about the nature of wormholes and how we would be able to interact with them – some scientists suggest they might lead to parallel universes. What is more, this might imply that if scientists were to create a wormhole successfully, we would only be able to access one point in space or time.

Minkowski Diagrams

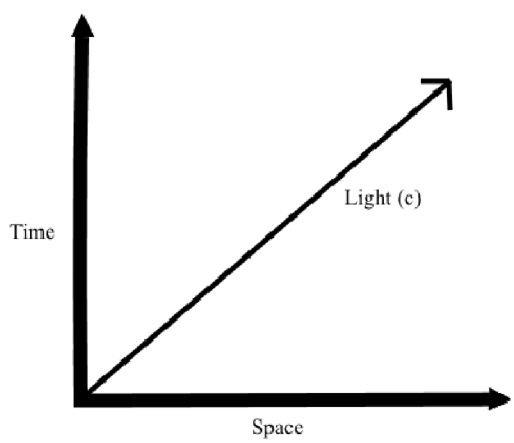

Figure 2

Also called space-time diagrams, Minkowski diagrams are a very helpful tool in describing situations involving the change of space and time. A very simple diagram is shown in Figure 2. In these diagrams, distance is given on the horizontal axis and time (typically represented as c*t) is on the vertical. The line represented on the graph is the "worldline" of light.

In space-time diagrams, worldlines symbolize a specific object's trajectory and the amount of time that the object takes to complete that trajectory.[9]

It is easy to imagine now, this diagram rotated three hundred and sixty degrees about the time axis, creating a two-dimensional spatial plane and a "light cone." Light cones are useful in discussions of time travel because they are a convenient way of drawing out an object's future

[8] For a fuller description of Einstein-Rosen wormholes, see Herbert, Nick. "Space Warps." In *Faster Than Light: Superluminal Loopholes in Physics*, 98 - 129. New York, New York: Plume, 1989.

[9] Minkowski diagrams are very helpful in resolving special relativity's Twin Paradox. See the previously referenced Nahin's "Proper Time, Curved World Lines, and the Twin Paradox" in *Time Machines*, pages 459 – 466.

(and also past). Consider two objects, then, in the same spatial plane that are a certain distance apart from each other. Both objects have a light cone, but the two objects are incapable of seeing each other until the time that their light cones cross.

To put it more simply in an example: it takes time for light to travel from the sun to reach the earth (about eight minutes). Hence, if the sun suddenly went out, it would take observers on Earth eight minutes to notice. Even when a friend is waving to you from across a street, light must travel that certain distance from their hand to your eyes. In this respect, it could be said that the only thing humans are ever able to observe is the past.

The Inspiration for the Models

The First:

As I mentioned earlier, the grandfather paradox has long been an issue facing discussions of time travel. This has given rise to Stephen Hawking's Chronology Protection Conjecture. The CPC suggests that anyone traveling back in time would be prevented from any violation of causality. In other words, the CPC suggests that if you were to ever to go back in time in your past, you had already done so. Recall our metaphor of time as a river. In this metaphor, imagine a small stream that diverges off of the main river and circles back into the river at another point – in the language of time travel, this would be called a closed time-like curve.

Under the CPC, if you were to go back in time and attempt to kill your grandfather, or yourself, or make any attempt to alter history as you knew it, you would fail. Perhaps you would slip on a conveniently placed banana peel at the last instant. But regardless of how you were foiled, anything you could have done to affect the outcome of things would already be part of your memory, because you had already lived through it.

Causality

Recall the CPC says causality is preserved. Causality, to put it in brief, is the notion that every effect has a cause and that the effect can never come first. More specifically, if A causes B, then it is necessary that A chronologically occurred first. This statement can be rephrased to if A happens before B, and if the two are causally linked, then A was the cause and B was the effect.[10]

As it turns out, causality is a way that many people and cultures have used to define what time is in itself. Time and history, this view suggests, is a domino effect of one cause creating an effect, which functions as the cause for another effect, and so forth, and so forth.

[10] Nahin 185 – 191.

The Second:

The inspiration for the second model comes from resolving the grandfather paradox via the conservation of matter (or more specifically, mass and energy). Antoine Lavoisier (1743 – 1794) was a pioneer of a scientist in being the first to show that the total mass of any closed system is conserved, meaning that the amount of matter within a system always stayed the same. Many stories about time travel like to invoke the grandfather paradox and suggest that preventing your birth would make you slowly disappear from existence.[11] Here is where I will invoke conservation of matter, the law of physics which says matter can neither be created nor destroyed. Even in a world where one is assuming that time travel is possible, it is impossible to violate one of the most basic laws of physics that governs our existence – assuming, that is, that you have not entered a new universe governed by seemingly new laws. It can be seen, therefore, that this model, as well as the first one, will be restricted to one time, or one worldline. I will show, then, how the second model assumes that time functions in the same basic way as the first, but that in the second, the CPC does not hold.

The Third:

The third model is inspired by the physics and philosophy that come from modern research in quantum mechanics. In QM, sometimes a radioactive source decays, and sometimes it does not. What the physicist has to do, then, is assume that the system is in a superposition of both possible states.[12] This leads to the notion that there are parallel universes – one in which the radioactive source decays and one where it does not. In fact, this can be extended to every

[11] Two notable examples of this in film include *Back to the Future* (1985) and *Looper* (2012).

[12] The famous example of this is Schrödinger's Cat. If a radioactive source decays in a box, then a mechanism releases that kills a cat trapped within a box. But, if the source does not decay, the cat is fine. Since the scientist cannot know whether or not the cat is alive or dead before opening the box, the cat is assumed to be a superposition of both states.

decision that you make every day, i.e. for every decision you have ever made, there could exist an alternate universe where you made a different choice. These parallel universes, although they can be thought of as "copies" of each other, are not able to physically interact with one another. As shall be seen in the descriptions of the models, the third model contains the possibility of parallel worldlines that would not be able to interact with each other. This model, obviously, does not require that the universe passes only through one distinct timeline.

A Note on One Timeline versus Parallel Times

The first two models restrict the universe to one timeline. Specifically that means that they are restricted to one existence that contains a past, a future, and a present for any observer at any given point in the world. This is an important distinction to make because the possibilities of parallel universes, and therefore parallel "copies" of oneself have a tendency to make people rethink what "the self" means to them, often to uncomfortable ends. As a result, it would be more comfortable to mankind's self-identity to believe that there could only be one existence. For the purposes of this discussion, though, we will consider both situations and see what derives from either assumption – the situations in which time is restricted to one timeline and when it is not.

Models of Time

Linearly Fixed Time

As previously mentioned, this first model follows in line with the Chronology

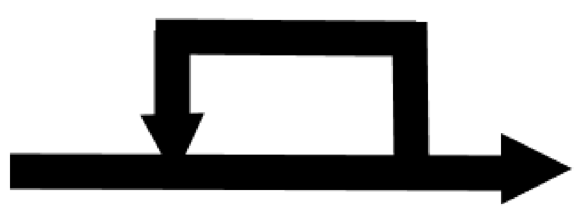

Figure 3

Protection Conjecture. In this model, all points of time are fixed with respect to each other and are moving in line with one another. A big assumption here, as we have discussed, is that there is one and only one timeline that can exist for the universe. Again, since we are assuming that the CPC holds, if this is how time functions, this would mean that any trip into the past you went on would have been something you have always done. Consider Figure 3.

Trace your finger from the left side of the diagram to the right, and follow the closed loop on your path. This is a representation of how traveling backward in time would work in this model. As an example, let us say that you are a scientist with a time travel machine in your laboratory, and you make the decision to send a cup of coffee to yourself in the past. “In one hour,” you say, “I will send myself a cup of coffee to this very moment.” Then, suddenly before your eyes a cup of coffee appears! After you enjoy the hot cup of joe, an hour later, you brew a new cup and send it back to your past self. Now, here you might notice we have a sort of reverse grandfather paradox. What if in one hour’s time, you make the decision to not send the cup of coffee? According to the tenets of the chronology protection conjecture, you would be physically bound by laws of causality of the universe to send that cup of coffee (so much for free will). Notice though that causality is saved, albeit circularly, in this model.

Issues with Linearly Fixed Time

But what if you then did not have to send the coffee back after having received it? This issue will be resolved by the second model. This model, rather, would also suggest that if anyone had ever traveled back in time to our past, we would already know about it. The “Where are all the time travelers?” argument has been made before and addressed many different ways. Perhaps the strongest answers, however, involve the limits on proposed time machines – recall the description of wormhole travel earlier, that might only be able to travel back to one specific point.

In a sense, then, this model is the simplest model because the universe is restricted to one worldline, and any trip to the past would be just as much a part of your past as it would be a part of your present and future.

Linearly Mutable Time

Let us now say you receive that cup of coffee, but then make the conscious decision to not send the cup back to yourself. Restricting the universe to only one timeline, this would imply that you are rewriting time as had been previously experienced. Think of time as having occurred exactly as in Figure 2, but altered by changing something about the past, i.e. by deciding not to send the coffee cup, or killing your grandfather, you change the past as you knew it. See Figure 4, where a traveler's journey first goes along the black arrow, and then the grey. Also notice in the figure that after making a change in time, one would, in effect, rewrite history (this is represented by the grey arrow along the timeline).

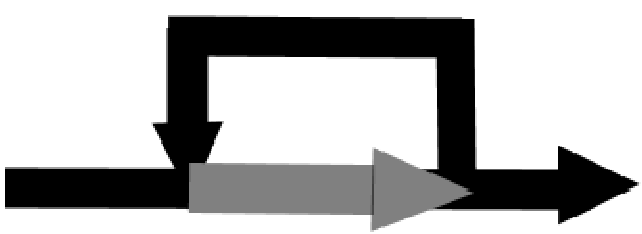

Figure 4

In this view, preventing one's birth does not mean that you suddenly cease to exist, but that you will live through a newly-formed timeline in which you are never born. Since this model is assuming that there can exist only one distinct timeline at any given instant, but it is alterable, it is given the title "linearly mutable."

As a further example, consider now two time travelers, A and B. A goes back in time and prevents the birth of B through some nefarious spy-versus-spy hijinks. A year passes and B makes the decision to go back in time and witness his turning six-months-old. When he arrives, he can find no trace of his existence!

Issues with Linearly Mutable Time

This model also brings up another unsettling question. This time around, let us start at the assumption that the timeline that we currently live in and experience has been untouched by time travelers. Then, an audacious time traveler decides to go back in time and assassinate Adolf Hitler with the idea that this would prevent many atrocities of the Second World War.[13] This, obviously, changes history as we knew it in a dramatic way. But then would a time traveler from that changed timeline, who decided to travel into the distant future, see his or her changed history's future or our history as we know it today?

To settle this question, recall how I have defined forward time travel in the section headed "Words of Warning." Pending discussion on the nature of the method (or the machine) that is doing the travelling, I am considering forward time travel to constitute removing oneself from time, letting that time continue on, and placing yourself back in at a later point. With this in mind, an observer not doing the traveling would see the traveler leave, live through that certain amount of time, and then see the traveler arrive back at a later point. Again, I will discuss what the traveler experiences during this interval later, I promise. But it can be seen by this example that instantaneous travel to the future could create logical problems with alternate futures in one

[13] Killing Hitler seems to be a commonly used example when discussing going back in time and changing the past. Most likely because his existence was such an integral part of the Second World War, but it is curious nonetheless. For more information, see Inglis-Arkell, Ester. "Are We Running out of Time to Kill Hitler via Time Travel?" Io9. August 6, 2012. Accessed April 1, 2015. http://io9.com/5932026/are-we-running-out-of-time-to-kill-hitler-via-time-travel.

timeline. Imagine that, in this model of time, our observer does go back in time and assassinate Hitler, and then using his or her "travel instantaneously to the future" machine, jumps forward to the point in time that he or she originally left. In this scenario, the traveler would not see a history in which Hitler had been killed, but instead history as had he or she knew it because that time had not yet been rewritten. But can we reconcile B's inability to view his own past after A has prevented it?

Multilinear Time

The issue of time traveler B not being able to travel into the past as he knew it can be assuaged if we do not restrict the universe to one distinct timeline. In the vein of quantum mechanics, and our metaphor of the river, consider the chance that changing the past creates a divergence in the river of time. That is to say, any change in the past would create an intangible and parallel timeline to the line the traveler left, as seen in Figure 5.

Figure 5

This would mean that if traveler A went back in time and prevented the birth of B, and thusly created a separate timeline, that B would still be able to go back and visit his own past. However, if B traveled to a point before A ever attempted to prevent B's birth, B would then be able to see A's attempt and maybe even stop him. This would, then, create yet another divergence. Consequently, the implication of this is that to an observer going through time, time flows along the most recently diverted path.

There is a key thing to point out about traveling through time under this model: traveling into the past and changing time as you experienced it, means that you could never return to the timeline you left. Keeping the scenario of travelers A and B in mind, let us say that after A has prevented the birth of B, A decided that the prank was well-done and wants to have a good laugh with B about it. But under this model, B has created an alternate reality in which A will never be born, and any attempts A makes at going to the future or the past will not result in being able to see B ever again.

A helpful way to picture this, is that of a dam that diverts the direction of a river. This way, anyone traveling from a point in the past travels along the most recently diverted path.

It is in this model that discussions of the quantization of time and the nature of the machine are most important. Because, if time is indeed quantized, then that means that there is a specific instant to which one could travel to in order to make a change, and that two travelers could each travel to the same exact moment in time. What is more, that also means that there is a distinct moment before and a moment after a time in which any change is made where beforehand a traveler could witness history as he knew it, and in the moment after he would witness a new history following the changed moment.

Issues with Multilinear Time

Perhaps the biggest issue facing the model of multilinear time is that if time is able to separate into two timelines, can two timelines join into one? I say no, because more parallel universes in existence means more entropy, or a decrease in predictability of order, and the second law of thermodynamics says that all closed systems must increase in entropy over time. In fact, many physicists use this as a definition of time and as part of proof that time is linear.[14]

A further response to this is that there is already something in nature that is observed to naturally split and not to naturally come together: nuclear decay in radioactive materials. Radioactive materials lose nucleons (through release of other particles) naturally, while nuclear fusion, or the coming together of nucleons, only occurs naturally in the universe in stars – and in those situations, the star can be thought of as a furnace that is doing work in order to achieve that fusion – but it has never been observed to occur unprompted on Earth.

[14] Cramer, "On Time Travel."

Corollaries to Multilinear Time

Is Time Quantized

Planck Time is defined by physicists to be the amount of time it takes for light to cross a specific distance (called a Planck Length) that is determined by Planck's Constant, or the smallest exchange of energy possible. In simpler words, Planck Time is the minimum amount of time that can pass between two events and it is calculated to be 5.39 x 10^{-44} seconds. This, however, does not mean that time moves forward in distinct increments.

The chronon was first proposed in 1927 by Robert Lévi, but a theoretical value for it was not suggested until 1997 in the paper "Introduction of a Quantum of Time, and its Consequences for Quantum Mechanics" by Ruy A. H. Farias and Erasmo Recami. In this paper, Farias and Recami argue that the length of a quantized amount of time for a given system is as follows:

$$\theta_0 = \frac{1}{6\pi\epsilon_0}\frac{e^2}{m_0c^3}$$

(Equation 1)

Modern research into whether or not time moves in distinct increments, i.e. chronons, has not yet been experimentally determined, and there are unfortunately few scientists who have published possible experiments or any discoveries on the topic. This may imply, rather, that time moves in a seamless continuum.

On the other hand, Plank's Constant, the smallest unit of energy exchange possible, can be experimentally determined many different ways (many of which are done in undergraduate physics labs). This quantization of energy per second, and subsequent quantization of length, may indeed imply that time can be quantized as well. Only the future can tell which of the two will be true.

Nature of the Method

A quick way to undermine the model of Multilinear Time might be to say, “In order to create this new parallel universe, where does all of that new matter come from?” This is where the nature of the method of traveling becomes important. If the method of time travel into the past involves a wormhole, we have two possibilities:

A.) Rather than connect two points in space of the same universe, wormholes connect two identical yet parallel universes (perhaps leading to different places or times).

B.) Via the nature of wormholes, rather than connect two points in space, they connect two points in time in the same universe.

If A.) were true, then traveling through time would affect the timeline of the universe much in the way of the Linearly Mutable model, but from the traveler’s perspective the universe would seem to function under the Multilinear model. Here, we have no worry about creating new matter, because this suggests that there are indistinguishable parallel universes full of the same matter in ours that are connected by the wormhole in question.

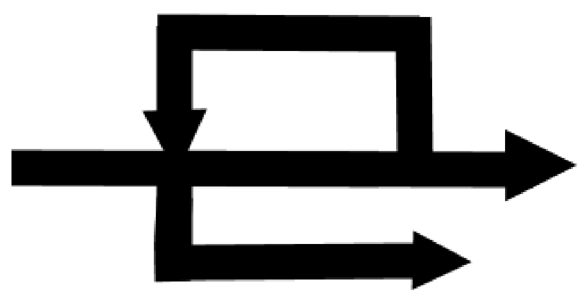

Figure 6

If B.) were true, then this gives rise to what are called temporal loops. A temporal loop, much like what is represented in Figure 3, often requires that the traveler experience the amount of time that they are traveling back.[15] Once the traveler arrives in the past, by changing it, he creates a new timeline using all of the matter that was already existing at that point in the universe and the matter that made up the previous timeline continues existing on its own. See Figure 6.

A Note on Holes to Specific Points

As we briefly addressed earlier, there is a possibility that we have never seen time travelers before because wormholes connect two specific points of time and space. If we assume, then, that one day scientists will be able to build and/or control a wormhole, that means that the one end of the hole that the scientists have created is fixed either to that place or that time. A time machine like this would only be able to go so far back in time as to the date that it was created.[16]

On Changing the Past

Postulate: Assuming chronology protection is false, any trip to the past changes history as understood from the timeline you left.

The reader may be curious as to what events constitute a change in history and what do not. If a time traveler went back in time and sat in a cave for the rest of his life, would that create a divergence in the timeline or rewrite history? Yes. Simply by nature of the matter that makes up the traveler's body, there is a displaced volume of particles that had to go somewhere else in the universe, as well as effects from your body's gravitational field that had not previously been there. Because of this, under the assumption that chronology protection is false, a time traveler's mere existence in the past would change history as he previously knew it.

Experiments to Lend Credibility or Discredit the Models

[15] For an excellent example of this in film, see *Primer* (2004).

[16] This is argued for in detail by Thorne, Kip. *Black Holes and Time Warps*, 501 - 505. New York, New York: W. W. Norton & Company, 1994.

The Experiments

Let us now assume that a friend has brought you a device which he claims is a time machine. Provided below then is a list of ideas for some experiments to carry out, in descending order, which will serve as evidence for or against these models.

1.) Make the conscious decision to send yourself something, and carry that decision out.

    Recall our example of sending yourself back in time a cup of coffee.[17] If you make the decision to send yourself back a cup of coffee, and then suddenly a cup of coffee appears, this is strong evidence that time behaves linearly fixed. On the flipside, if nothing appears before you and then you send yourself back the cup of coffee and you never see it again, this is evidence that suggests time behaves in another model. Note that this is assuming that the time machine actually works and that you did not just obliterate a perfectly good cup of coffee.

2.) Make the conscious decision to send yourself something, and do not carry that decision out.

    One of two things will then happen. If no cup of coffee appears before you in this case, we still have the possibility that the linearly fixed model (or really any model for that matter) holds true. However, if a cup of coffee does appear before you and you make the decision to not send yourself the cup following that, we have evidence to suggest that our decisions can alter the past – lending credibility to either the linearly mutable or multilinear models.

[17] While a clock, or a stopwatch, might be the more scientific and logically-sound object to send, the author is incredibly grateful to coffee (without which many of these ideas would not have come to fruition) for getting him through most of his life. So we shall continue with the example of cups of coffee.

3.) Send an object to yourself yesterday, and after one day has passed, send yourself (or an observer) into the past half of a day to check on the object.

First note that the time scale of a day and a half-day are arbitrary. What is important for this test is that the length of time that you sent the object passes and you then send yourself (or an observer) to a time longer ago than that. Obviously, if a day ago you received the package, then time is likely linearly fixed. But if time is not linearly fixed, and to you the object was distinctly not part of the past in your life as you knew it, there are two possibilities. If you travel into your past and see the object, this is evidence to suggest that time is linearly mutable, i.e. you rewrote your past when you sent an object back in time, and you are now rewriting history. Conversely, if you go into your past and can find no record of the object, this is evidence to suggest that time behaves multilinearly and that you created a divergence in time when you sent the object back, but still have the freedom to visit the past in your own timeline as you knew it.

Example of Experiment 3

Imagine that we have determined that the universe in which we live is not linearly fixed. Let us then send back in time the gift of a puppy on the day you were born. For the purposes of the example, we will assume that you and the puppy grow up as best friends. After a year passes, we will go back to when you were six months old and see how you and the puppy are getting along. If you see six month year old you playing with the beloved puppy, then this suggests that time is linear and mutable. Conversely, if you were to find the six month old you exactly as you remembered having lived through, and no record of the puppy at all, this would suggest that time is multilinear.

Should This Be Considered Science?

I would loosely define science as anything that follows what is known as the scientific method. That is, anything that consists of testable predictions of hypotheses that are made based on observations of the universe. While we do not currently have the ability to send objects, let alone people, through time, I would say that these are hypotheses that although are not yet testable, hopefully one day they will be. I have done my best to keep these hypotheses scientific, though. After all, claiming that time moves from past to the future is entirely based on observation.
So all in all, while under my definition these claims are not wholly scientific, I have followed what parts of the scientific method that I can and I hope one day study of time travel will be fully considered a science.

Is there Modern Research on Time Travel?

The answer to that question is yes, but very little. Since there are few experiments that can be carried out, there is little research published on actual time travel. Some experiments have attempted to prove or disprove causality, but little progress has been made in any direction. Perhaps the most perplexing experiment that may violate causality is what physicists call "action at a distance." In what is known as the EPR experiment, two particles are sent off in two directions, but a measurement on one particle affects the second particle even when they are incredibly far apart. While there is certainly something happening in this situation that physicists do not currently understand, one accepted explanation is that there are not-yet-understood superluminal forces acting on the two.[18]

The Possibilities of Time Travel

If a solid proof that time travel is impossible comes along, then I suppose I have provided the reader with a very thorough account of different ways time cannot function. But as we proceed into the future, more and more experiments on the nature of time will be performed. We previously discussed the idea of a wormhole that connects two points in time, which would mean that time machines would only be able to go back to the point in space and time at which they were created, but what about other possibilities?

Briefly mentioned in the discussion on the Tipler Cylinder, many physicists believe that the most possible method of traveling through time would be using an incredibly dense material around a traveler. In Einstein's relative universe, masses have the ability to warp space (and therefore time) around them. Thus, an incredibly dense material – denser than any material currently known – might be able to be used to warp space-time so drastically that it can loop around a traveler.

I remain hopeful that one day experiments on the nature of time and new ways of traveling through it will come to full realization. Travel through time has, however, captivated the minds of humans ever since we understood the concept of past, present, and future. And I believe that it will carry us into a future of even greater understanding.

[18] Herbert, 178 – 181.