IS TIME TRAVEL POSSIBLE?

When we research deeply into the possibilities of time travel, we get to know some paradoxes that challenge the theories of modern physics. Firstly, I will be examining the nature of linear and cyclical time and if our current understanding of this allows for possible time travel, in the second part of the writing, I will consider the 'Block Universe' theory and 'presentism' and if this allows for the possibility of time travel. Then I will analyse Einstein's (1905) 'Theories of general relativity and special Relativity' and the Godel Solution to discern if time travel could happen one day. Next, I will explain what time dilation is with an equation came up by Einstein. Finally, I will be examining some famous theories and paradoxes related to time travel, which will be useful to come to a proper understandable conclusion of the possibilities of time travel.

Introduction

Time traveling is the hypothetical ability to move between different points in time often known as the fourth dimension. Time is called a dimension as dimensions arise when a force is generated, which allows movement into a new domain (Wikipedia, 2023). According to Wikipedia (2023), this idea and theory of time traveling has caught the human imagination. The idea of time travel has a long history that runs back centuries. Ancient stories like the Indian Mahabharata and Popol Vuh contain elements of time manipulation (Christenson, 2003). On the other hand, medieval works such as Divine Comedy by Dante Alighieri explore journeys through different temporal realms (Crable, 2021). However, Wells (1895), the novella "The Time Machine" mentions, the modern idea of time travel in popular culture raised widely, and where Wells (1895) introduced a device that can move freely through time. Hence, we can comprehend that humans are fascinated and intrigued by discussing time travel over many generations.

Linear time and cyclical time

Now the writing will turn its idea towards the concepts of linear model of time and cyclical model of time while giving more attention to the cyclic model of time. The linear model of time is a Western ideology that considers time as a one-way progression from the past to the future (Fuchs, 2021). In contrast to this Fuchs (2021) mentions that many ancient cultures and religions believe time is cyclical with events repeating in an eternal loop. Some of these religions are Hinduism, Buddhism, and Jainism (Thomas, 1997). According to Buddhist cosmology, time is cyclical as Buddhist people believe living beings go through different cycles of existence based on their karma repeating birth, death, and rebirth (Department of Religion and Theology, University of Bristol, 2024). Similarly, according to Ravi, et al., (2023), Hindu people believe the universe goes through endless cycles of creation, preservation, and destruction. Further Ravi, et al., (2023) posit that this cycle consists of 4 Yugas (ages) which are Satya Yuga, Treta Yuga, Dvapara Yuga, and Kali Yuga. Jain cosmology states time as Kalachakra (eternal wheel) with 2 halves known as Utsarpini (ascending time wheel) and Avasarpini (descending time wheel) (HereNow4U, 2006). According to HereNow4U (2006), this cycle repeats continuously with each half marked by a rise and fall in well-being and human virtues.

Ancient Greek philosophers such as Stoics, believed time is cyclical as they posited the idea of eternal recurrence (Batchelder, 1998). Further, this teaches that the universe undergoes destruction (ekpyrosis) and rebirth in an infinite cycle. According to Aztec civilization, Aztecs also believed time is cyclical as they have a theory that each sun is being destroyed and a new one is created (ELZEY, 1974)

Further, they believed we are currently living in the fifth sun. Similarly, ancient Egyptians also believed time is a cycle of life, death, and rebirth in relation to the soul and the god of the sun Ra (Clark, n.d.). Further, Egyptians believed Ra reborn every morning after journeying through the underworld.

However, according to (O'Shea, 2012) in 1781 Emmanuel Kant published "Critique of Pure Reason" where he argued that time is a human construction/framework which we perceive events, while Henri Bergson proposed the concept of "duration" in 1889 in his work, "Time and Free Will" (Moravec, 2023). In this he said, duration is always an interval and never instantaneous, therefore always marked by differences of past and present.

Block Universe Theory and Presentism

Now the writing will focus on Block universe theory and presentism are two dominating theories when discussing time in modern physics and philosophy. According to (Bourne, 2006), Presentism can be categorized into 2 parts as philosophical presentism and historical presentism. Further, in philosophical presentism, the past and future entities do not exist, and only present entities exist! However historical presentism refers to interpreting past events through the lens of modern values and concepts. The block universe hypothesis holds that past, present, and future occurrences are all equally real and exist in a four-dimensional spacetime continuum. It is sometimes linked to the philosophical viewpoint known as eternalism. The implications of special relativity, in particular the relativity of simultaneity, which postulates that all events coexist in a fixed spacetime structure even though different observers may disagree on the timing of events, are the main source of this viewpoint (Silberstein et al., 2018; Ellis & Rothman, 2010). The block universe concept suggests that time is a dimension like space, where all moments in time are equally legitimate, challenging our intuitive notion of time as a flowing entity (Short, 2017; Peterson & Silberstein, 2010).

This view aligns closely with Einstein's theory of general relativity where time is treated as the 4^{th} dimension. According to this theory time travel is theoretically possible as someone can easily travel to different points in the spacetime continuum.

The relationship between time and general relativity

According to Einstein's general theory of relativity, mass causes spacetime to curve, which results in gravity. The presence of closed timelike curves (CTCs), which are spacetime trajectories that loop back on themselves and, in theory, let an observer go back in time, is made possible by this paradigm (Lloyd et al., 2011; Tobar & Costa, 2020; Dolanský & Krtouš, 2010). Significant queries concerning causality and the nature of time itself are brought up by the existence of CTCs. Paradoxes like the grandfather paradox, in which the time traveler might stop their own existence, could result, for example, from interactions with their former self (Tobar & Costa, 2020; Kupervasser, 2014).According to (Pfarr, n.d.)The famous answer for Einstein's equations involving CTCs is Godel solution which suggests that in a rotating universe, time travel might be theoretically possible! (Godel solution was proposed by Kurt Godel in 1949).

General Relativity and Special Relativity

According to (Miller, 1998), Einstein's Special theory of relativity was published in 1905 and introduced the concept that time is not a fixed constant, yet can stretch or contract depending on an observer's speed. Simply, according to the theory states that time moves faster for objects that are accelerating and that no object can move faster than the speed of light.

Further, time dilation is one of the key predictions of special relativity. This means time passes more slowly for an object moving at speeds close to the speed of light compared to an object at rest.

This idea is crucial for understanding forward time travel. Further, a person traveling closer to light speed could experience minutes or hours while centuries pass on Earth. This form of time travel into the future is not speculative, but a well-accepted consequence of special relativity.

According to (Hendrik Antoon Lorentz, 1952), Einstein's General theory of relativity was published in 1915 and expanded upon this by introducing the concept of spacetime curvature. Further, according to general relativity, enormous objects bend spacetime and this curvature affects time. Clocks run more slowly in stronger gravitational fields, which is known as gravitational time dilation. This provides a theoretical pathway for time travel, especially near massive objects (large bodies) like black holes and planets.

Albert Einstein realised in 1949, that his own equations allow to go backward in time. If the universe were to rotate for example and you went with the flow you can go around the universe and come back into the past. According to (Paul Davies, 1996), when Einstein did more research about it, he found a loophole which is universe only expands not rotates. So, time travel was not possible according to this.

Time dilation

Time dilation is major evidence to show time travel is possible. When time passes at different rates for different observers. Time moves more slowly for a moving observer than for a stationary observer. It occurs because the clock of moving observer moves more slowly than stationary observers.

(Equation used to calculate time),

Time Dilation Formula

$$t' = t\frac{1}{\sqrt{1-\frac{\vec{v}^2}{c^2}}}$$

Figure 1 time dilation equation - Search Images

t' = dilated time t = stationary time

v = velocity c = speed of light

According to (Buzzo, 2014), the dilation effect (y)is approximately 1 unless our velocity is a substantial fraction of the constant speed of light. Therefore, we don't usually notice the time dilation as we can't move faster than the speed of light. Further, the fastest speed most human will be able to achieve, an aircraft travelling closer to the speed of sound gives a time dilation where (y) is 1.00000000000005 seconds for a stationary observer. Therefore, for the stationary observer time passes more slowly than to the moving observer.

According to (Martin, 2023), in 1971 J.C. Hafele and R.E. Keating carried out the experiment, placing two caesium clocks on passenger aircrafts and flew them in opposite directions around the globe to experiment with a hypothesis first posited in Albert Einstein's theory of special relativity. Their goal was to measure the effects of relativity on these accurate devices. Further, according to the predictions from the eastward flying clock would lose 40ns and the westward flying clock would gain 275ns. (1 ns = $1x10^{-9}$). One nanosecond is to one second as one second is to 31.7 years. However, the results showed that when compared to stationary clocks at the lab, the eastward clock has lost 59ns and the westward clock has gained 273ns. This experiment is commonly held up as one of the first to give practical evidence of the physical effects of time dilation.

According to (Buzzo, 2014), as in Reinhardt et al note (2007), "time dilation is one of the most fascinating aspects of special relativity as it abolishes the notion of absolute time". Further, in their 2007 article, they tested the effects of time dilation with even more accurate atomic clocks by adding more experimental evidence consistent with special relativity. There are also other experiments such are those on muon decay (F Riggi *et al* 2016 *Eur. J. Phys.* **37** 045702), which provide additional experimental evidence that the effect is described as real and measurable.

While we don't accelerate humans to the speed of light 3x10^8 m/s, we send them swinging around the planet at 17,500 mph aboard the International Space Station. According to (Nahin, 2011), astronauts Scott Kelly and his twin brother Mark Kelly are real life examples for time dilation. Scott spent 520 days in orbit while Mark was in space for 54 days. Further, the difference in speed they experienced time over the course of their lifetimes has actually widened the gap between their ages by 5 milliseconds as previously the gap was 6 minutes.

Now let's focus on Stephen Hawking's views on the possibilities of time travel.

Stephen Hawking frequently discussed the idea of time travel in his writings and was renowned for his deep understanding of the nature of space, time, and the cosmos. He noted the potential drawbacks and contradictions of time travel, even if he was receptive to the idea in some circumstances. Hawking's expertise in cosmology, quantum mechanics, and general relativity framed his opinions on time travel. He stated the following main points about the possibility of time travel:

Hawking admitted that time travel would theoretically be feasible given the principles of physics. He specifically cited the general relativity equations, which imply that time is a dimension that may be distorted by the existence of mass and energy rather than a constant. The idea of a "wormhole" a tunnel-like structure in spacetime that may, in theory, connect distant points in space and time is one of the most well-known solutions to Einstein's equations that suggests time travel.

However, exotic conditions, such as "negative energy" or other forms of exotic matter that have not yet been found or understood, would be needed to create or stabilize a wormhole in a way that would allow for time travel. The energy required to manipulate spacetime to such an extent is beyond anything we could currently achieve.

Hawking asserts that this is the possibility of paradoxes, including the well-known "grandfather paradox." If you go back in time and do anything that would stop you from being born, like killing your grandfather, this paradox would occur. Since it would suggest that you could never have existed in the first place to travel back in time, this would lead to a logical contradiction.

In order to resolve these contradictions, Hawking proposed the concept of "chronology protection." In order to avoid such logical conflicts, he proposed that time travel to the past might be somehow prohibited by the rules of physics. This theory suggests that the cosmos may have inherent systems that guard against temporal loops, guaranteeing that causality—the link between cause and effect—is always maintained.

Hawking was more hopeful about time travel to the future than he was about time travel back in time. The idea that time is going forward is actually important to both general relativity and our perception of time passing. According to Einstein's theory, time advances differently depending on an observer's relative velocity or the strength of the gravitational fields they are experiencing.

For instance, time would move more slowly for someone traveling close to the speed of light than it would for someone on Earth. Time dilation is the name given to these phenomena, which has been verified by experimentation. As we advance through time at a pace of one second each second, Hawking contended that time travel to the future is both theoretically feasible and something we all undertake on a regular basis. Ultimately, while time travel remains a fascinating subject of theoretical inquiry, Hawking's conclusions suggest that, based on our current understanding of the universe, the kind of time travel often depicted in science fiction is unlikely to be realized any time soon, at least not without new breakthroughs in our understanding of the cosmos.

Theories related to time travel

Let’s move on to some widely discussed theories about time travel which help us to get an idea of the possibilities of time travel in the near future.

Wormholes are a widely discussed topic when talking about time travel. Wormholes are also known as Einstein-Rosen Bridges (Seefeld, 2021). Further, the wormholes are hollow tubes through space and time that have the ability to connect universes or 2 separate regions in the same universe, even stars too. According to (Marie D. Jones, n.d.), theoretically, to stabilize a wormhole it may require exotic matter with negative energy density. Using wormholes you can go back in time. Further, the entrance to these wormholes is situated behind the black hole event horizon. A problem with this is if you cross it, you can never escape again.

According to (Svozil, n.d.), quantum mechanics also open a path to explore the possibility of time 0travelling. Some elucidations of quantum mechanics, such as many-worlds interpretation propose that every outcome of a quantum event can exists in its own separate universe. Further, this leads us to believe that concept of a multiverse is real and we can time travel into alternate timelines.

Superposition and quantum entanglement also present strange possibilities for time travel, but these theories are usually controversial (Medico, 2024). According to (Watrous, 2008), David Deutsch explored how quantum mechanics allow to CTCs, with quantum information sent backward in time. However, there are no experimental evidence to support them. Therefore, according to David Deutch time travelling is not possible!

When we dive deep into the possibilities of time travel, we face some challenging theories as well. One of them is **“Arrow of Time”**

According to (Carroll., 2010), “Arrow of time” is one of the major challenges to time travel as it refers to the fact that time appears to flow in one direction, from the past to the future. Further, this circumstance is related to the second law of thermodynamics. In this case time’s arrow points in the direction of increasing entropy. Therefore, time travel violates the second law of thermodynamics by allowing for decreases in entropy. However, according to (Zeh, 2007) some physicists have presented solutions, such as the time travel might be possible in regions of spacetime with reversed entropy.

The butterfly effect is a theory derived from chaos theory. Chaos theory is the study of unpredictable behaviour/events in systems. The butterfly effect suggests that small changes or actions in a system can be led to major unpredictable consequences over time. The term butterfly effect originates from an analogy in which the flapping of a butterfly’s wings in Wales, set off a chain of events that leads to a volcanic eruption in Indonesia.

According to (Ralph Abraham, n.d.), the butterfly effect was first popularized in 1960s to the world by Edward Lorenz, who was a meteorologist. While he was working on weather prediction models, he found that small rounding differences in the conditions of his equations led to different outcomes. However, the idea became central to chaos theory. Further, the butterfly effect shows that certain systems are highly sensitive to initial conditions which is an idea commonly referred to as sensitive dependence on initial conditions.

This gives the idea that even small changes made by a time traveler in the past could lead to huge changes in the present or future. For example, if a time traveler goes back in time and steps on a small insect by accident, this seemingly insignificant action of his/her could cause bigger problems in the future (such as – species going to extinction or evolving differently) according to the butterfly effect.

Furthermore, this idea has been explored in different ways in movies and fiction stories. Ray Bradbury’s short story “A Sound of Thunder” (Bradbury, 1952), is one of the most famous examples. In his story, a time traveler goes back to the Jurassic time and accidentally kills a butterfly. After he returns to the present, he finds out that the entire world has changed because of this small action he did by mistake. This story of Ray Bradbury’s encapsulates how frangible and interconnected the flow of time can be fortifying the dangers of altering the past which express time traveling is risky.

<u>Paradoxes</u>

Now to give an idea of time travel and its relevance an important notion of paradoxes introduced in the fields of physics are introduced.

According to (Wasserman, 2018), time travel paradoxes are generally categorized into either**:** Closed casual loops or Consistency paradoxes. Further, closed casual loops occur when a cause is fulfilled through an action brought about by time travel to the past. Examples include the predestination paradox and the bootstrap paradox. Further, consistency paradoxes occur when the cause is prevented from ever occurring by an action brought about by time travel to the past. (Polchinski's Paradox, Hitler's Paradox, and the Grandfather Paradox are a few examples.)

The grandfather paradox is one of the most famous paradoxes linked with time travel and is one of the basic paradoxes that explains the effects of time travel and how that can affect the time traveller.

According to (Stewart, 2010), the paradox arises when the time traveller goes back in time and interacts with their grandparents in a way that prevents his/her parents from being never born and this prevents the time traveler's own birth. However, this creates a logical unpredictability if the time traveller was never born, how could he go back in time and interact with his/her grandparents to prevent his/her parents' existence?

Bootstrap paradox refers to the idea of the ability to "pull oneself over a fence by one's own bootstraps". This idea has been popularized by the sci-fi writer Robert A. Heinlein (Heinlein, 1941) .This book tells the story of Bob and how he used his time travel portal to encounter time travel paradoxes.

Further, Bootstrap paradox occurs when an object is sent back in time becoming the cause of itself in the future. As an example, Barry Allen, (The Flash, 2023), a fictional character travels back in time and gives Shakespeare a copy of his own works which Shakespeare uses to write his plays, thus erasing the original source of the knowledge.

However, this theory raises questions about the nature of causality and the flow of information in time. If an event is both cause and the effect of itself, we get the question, is it violating the principle of causality or is it pointing to a more complex relationship between events and time? Therefore, we face a problem where we are unable to conclude whether time travel is possible or not.

Predestination paradox - According to (Couenhoven, 2018), this paradox occurs when the actions of someone who travels back in time become part of the past events and ultimately cause the event he is trying to prevent to take place. Further, this results in occurring a temporal causality loop, where the first event in the past influences the second event in the future (time travel to the past) which causes first event to occur. Further, this cyclical loop of events ensures that the history isn't altered by the time traveller, and any attempts to stop something from happening in the past will lead to the cause itself instead of bringing to an end. Simply the predestination paradoxes propose that things are always bound to happen the same way and that whatever has happened must happen.

An example for a predestination paradox is, in the movie (The time machine , 2002), Doctor Alexander Hartdegen witnessed his fiancée being killed by a mugger which led him to build a time-traveling machine to travel back in time to save her. However, his attempt failed leading him to conclude that, he could come back a thousand times only to see her die in a thousand ways. Later, Über-Morlock told Hartdegen "You built your time machine because of Emma's death. If she had lived, it would never have existed, so how could you use your machine to go back and save her? You are the inescapable result of your tragedy, just as I am the inescapable result of you". This shows us the fact that, even though you travel back in time and try to change your fate, there will be coincidences to your own actions.

Now this dissertation will focus on the latest thinking surrounding the possibility of time travel while exploring deep into theoretical frameworks, paradoxes, and implications of such phenomena.

Einstein's theory of relativity serves as the foundation for current debates over time travel. This theory holds that time is a dimension that is entangled with space, creating a four-dimensional spacetime continuum, rather than a fixed object. According to Smeenk and Wüthrich (2011) and Lloyd et al. (2011), this viewpoint permits the potential possibility of closed timelike curves (CTCs), which are spacetime pathways that loop back on themselves, allowing for a type of time travel. CTCs have significant ramifications since they cast doubt on our accepted notions of causation and chronological order by implying that, in some circumstances, it would be feasible to go back in time (Ringbauer et al., 2014).

Wormholes are a well-known possibility among the many processes that have been investigated in recent literature as potential time travel facilitators. Wormholes are hypothetical passageways across spacetime that potentially link far-flung locations in time and space, as predicted by the Einstein field equations (Zahra, 2023). Many physicists have studied the possibility of using wormholes as time machines; some contend that they could enable forward time travel, while others warn of the paradoxes they create (Shoshany & Jared, 2021). To preserve the integrity of causality, Hawking's chronology protection theory, for example, suggests that the laws of physics might forbid the creation of CTCs (Shoshany & Jared, 2021).

Paradoxes such as grandfather paradox, challenge the notion of determinism and prompt discussions about the nature of free will in a time-travel context. Vihvelin's work on the conceptual and metaphysical possibility of time travel highlights the tension between determinism and the potential for altering past events (Vihvelin, 2023; Fernandes, 2018). This philosophical inquiry is essential for understanding the implications of time travel on our conception of reality and personal agency.

Furthermore, there has been a lot of interest in the relationship between time travel and quantum mechanics. Time travel may be more possible than previously believed, according to quantum theories, especially when considering post-selected teleportation and other quantum phenomena (Lloyd et al., 2011; Allen, 2014). According to Ringbauer et al. (2014), these theories suggest that time travel and quantum mechanics could be reconciled, enabling self-consistent narratives that steer clear of the paradoxes commonly found in classical time travel scenarios. In addition to broadening the theoretical horizons, the examination of quantum time travel encourages experimental studies of causation and time.

The implications of time travel extend beyond theoretical considerations; they pose ethical and existential questions about the nature of human experience. If time travel were possible, it would fundamentally alter our understanding of history, memory, and identity. The potential for individuals to interact with their past selves raises concerns about the moral ramifications of such actions, as well as the psychological impact on the time traveler (Younus, 2023). The exploration of these themes in literature and philosophy underscores the profound effects that the possibility of time travel could have on human consciousness and societal norms.

Therefore, we can understand that even though there is a possibility to time travel, it will be dangerous and a complex process.

In conclusion, the possibility of time travel continues to be one of the most fascinating and challenging issues in philosophy and science. The current discussion on time travel covers a wide range of topics, including theoretical physics, philosophy, and ethics. Time is not a fixed thing, the philosophical ramifications of such possibilities challenge our understanding of reality, causation, and human agency, even as the scientific community continues to investigate the viability of time travel using frameworks like relativity and quantum mechanics. According to theoretical frameworks like Einstein's relativity, which opens up possibilities for time travel, especially through ideas like wormholes and time dilation. But the paradoxes that emerge—like the grandfather paradox—challenge our knowledge and bring up important issues regarding causality and the nature of time itself.

The theoretical character of time travel keeps it firmly in the realm of theory rather than practical reality, even while scientific discoveries continue to broaden our understanding. In the end, the feasibility of time travel may rely on our philosophical understandings of time and existence in addition to developments in physics. As of right now, it continues to be an intriguing idea that challenges us to consider the boundaries of our knowledge and the secrets of the cosmos. The discussion around time travel will surely change as research advances, leading to more investigation into its possibilities and how it might affect our perception of time.

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