MODELS OF TIME TRAVEL

A COMPARATIVE STUDY USING FILMS

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DECLARATION

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma at any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except when due reference is made in the text. The empirical work described within was not carried out with any other person.

Guy Micklethwait

In the year of '39 came a ship in from the blue

The volunteers came home that day

And they bring good news of a world so newly born

Though their hearts so heavily weigh

For the earth is old and grey

To a new home we'll away

But my love this cannot be

For so many years have gone

Though I'm older but a year

Your mother's eyes in your eyes cry to me.

Don't you hear my call, though you're many years away

Don't you hear me calling you

All the letters in the sand cannot heal me like your hand

For my life, still ahead, pity me.

Extract from the lyrics of *'39* by Brian May (1975)

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ABSTRACT

This research identifies the way the science of time travel is presented to the public through the medium of feature films, and discovers if this can be used to construct a comprehensive set of models about time travel and its consequences.

There is no universally accepted understanding of what constitutes the nature of time. Even though the fundamental laws of physics do not prohibit time travel, scientists and philosophers do not agree about what would happen if backwards time travel ever became a reality.

I identified models that scientists and philosophers have produced about the nature of time, time travel and other temporal phenomena. I then determined the model of time used in each of the 100 time travel films that I reviewed. I also used a verbal survey to elicit the personal models of time travel for each participant of three focus groups I conducted with members of the movie-going public. I compared these models of time with the personal models used by members of the movie-going public and synthesised them to develop a comprehensive set of 21 models of time. The 'guyline' diagrams that I devised proved to be a very useful tool for analysing how the timelines of the time travellers behaved in each film.

My research has shown that an investigation of time travel in films can indeed be used to construct useful models of time based on the evidence of the 21 models that I developed. Furthermore, I showed that both my models of time travel and my guyline diagrams helped to structure conversations about time with members of the movie-going public. The findings of this thesis can be used by scientists, philosophers, filmmakers and the public to help them clarify our thinking about time travel, the nature of time, how it is communicated, and also in future research.

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I know well enough what [time] is, provided that nobody asks me, but if I am asked what it is and try to explain, I am baffled.

– Augustine of Hippo (354 – 430), philosopher and theologian[1]

Time has fascinated me since my childhood. In my twenties I pondered the nature of time, particularly how space and time could not exist without each other. In my thirties I wondered why the separation that space and time describe collapse into a oneness when the mind shuts down during deep sleep. I had also temporarily experienced this oneness made up of everything and nothing while practising deep meditation.

When I sustained a head injury in a motorbike accident my brain suffered a lot of bruising, and it was difficult for my mind to work properly. I remember lying in a hospital bed fully awake, but not able to use my mind to process any thoughts. I was not able to differentiate any one object from another, there was no separation between anything and time did not exist for me. Objects were moving, people were coming and going from my room, but from my perspective it was all happening at once because space and time were not present; this lasted for more than a day. When my bruised brain began to heal, I slowly started to experience the world in the way that most others do, and I returned to live a normal life – except that the memories of this experience remain with me today as if they only happened yesterday. As a result, I became interested in the philosophy and science of time, and how they compare to the public perception of time. These experiences inspired me to undertake my research in this area and have led to this thesis.

[1] Cullhed (2001).

CHAPTER ONE: INTRODUCTION

> *One of the more intriguing parallels between science and science fiction is the fascination both have with time.*
>
> - Lambourne, Shallis, & Shortland, authors[1]

Fiction involving time travel first became popular during the 19th Century. For example, in *A Christmas Carol* by Charles Dickens (1843), ghosts take Scrooge on return trips to his past and probable future. *A Connecticut Yankee In King Arthur's Court* was a fantasy novel by Mark Twain (1889) in which his protagonist makes an unintentional return trip to the distant past. Then H.G. Wells (1895) wrote *The Time Machine,* a science fiction novel in which a time traveller makes a return trip to the future in a time machine he built using the premise that time is the fourth dimension. By 1960, several film adaptations of these novels had been released, which helped to bring the concepts surrounding time travel into the consciousness of the movie-going public. Over the years, the popularity of this genre increased; the number of films released involving time travel or other temporal phenomena continued to grow until the end of the century.

All of these films use some implicit model of time travel: most have rules about how time works in the past and/or in the future, and they all involve a new 'timeline' that, for example, can replace the original timeline, or exist in parallel to it. These different models are used to convey to the audience how time is used in the plot. However, these models of time travel have not to my knowledge been formulated and recorded in the literature.

Time travel is just one kind of temporal phenomenon; others include rewinding time, stopping time, fast forwarding time, and splitting a timeline into two or more parallel versions. For the purpose of brevity in this thesis, from this point onwards, when I mention films involving time travel, I am referring to films that involve one or more of these types of temporal phenomena.

[1] Lambourne, Shallis & Shortland (1990).

Theoretical physicists have proved that the fundamental laws of physics do not prohibit time travel. Nahin (1993, p. ix) writes, "Time travel was once solely the province of science-fiction writers [but] how times have changed! One now finds scholarly analyses of time-travel in serious scientific journals written by eminent theoretical physicists." So, although time travel was once confined to fantasy and science fiction, it is "now simply an engineering problem" (Kaku, 2003).

The problem is that physicists do not all agree about what would happen if a person, an object, or some information were to travel back through time. Philosophers as well as physicists disagree on whether or not changes to the past would be possible.

Chaos theory is the area of scientific research that includes the 'Butterfly Effect', which "alludes to the idea that the flutter of a butterfly's wings in Brazil may set off a chain of events that, over time, leads to a tornado in Texas" (Riley, 2006). So the smallest of changes to a past event could cause a completely different future to unfold (as in *A Sound of Thunder,* the famous short story by Ray Bradbury (1952), which became a film of the same title.[1]) However, many people do not agree that a timeline could be replaced, as this might cause temporal paradoxes. Philosopher David Lewis (1976, p. 149) in his landmark paper *The Paradoxes of Time Travel* concludes, "We might expect that when a time traveler visits the past there will be reversals of causation…. Could a time traveler change the past? It seems not: the events of a past moment could no more change than numbers could."

Time travel "continues to produce a fruitful cross-fertilization of ideas between scientists and philosophers as theorists in both fields struggle to resolve confounding paradoxes that emerge when time travel is pondered seriously" (Joel Hunter, 2004). For example, the grandfather paradox occurs when a time traveller goes back and changes the past to the extent that they will never be born. One solution to this paradox is that if a time traveller's presence caused such a level of interference with events, the timeline would split into two. An alternate timeline would then exist in a parallel universe. Deutsch (quoted by Highfield, 2007) says that "Many sci-fi authors suggested time travel paradoxes would be solved by parallel universes, but in my work that conclusion is deduced from quantum theory itself."

[1] Released in 2005, this film was directed by Peter Hyams and is reviewed on page 374 of Appendix I.

Nevertheless, not all physicists agree that our universe can have parallel worlds, as many prefer Novikov's Principle of Self-consistency, which is a "conjecture on how nature may enable the laws of physics to accommodate time travel" (Nahin, 1993, p. ix).[1]

Causal loops can only occur in a universe where closed time-like curves (CTCs) exist, and these are consistent with the general theory of relativity.[2] In a causal loop, information that comes back from the future can cause changes that end up causing the predicted event to take place. This is known as a self-fulfilling prophecy, and a famous example is the ancient Greek legend of Oedipus.[3] A predestination paradox can also take place within a causal loop. This is when changes that a time traveller makes to the past end up creating the present they came from. The time traveller must go back in time in order for the self-consistency of his timeline to be maintained. A causal loop implies that all past and future events are fixed in time and that although the future is unknown, it is pre-determined. However, not everyone is entirely convinced about causal loops: Mellor (1998, p. 131) argues against the possibility of time travel by arguing against the possibility of causal loops; whereas Hanley (2004, p. 123) disagrees by arguing that "they are neither logically nor physically impossible." Lewis (1976, p. 74) is uncommitted, "Perhaps there must be loops if there is reversal; I am not sure."

There is also the possibility of mental time travel. In the *World Encyclopedia of Time*, Anderson (2010) asks if it is possible "that the human mind could master time? Or is it possible that the human mind itself is a time machine?" In a review of recent findings, Grondin (2010, pp. 573-574) states, "Psychological time is a very elusive object of study [and] the past 25 years have seen a multiplication of theoretical propositions, including those embedded within a neuroscience perspective, to account for the ability to process temporal information."

There is an ongoing debate in philosophy about the nature of time, which came to the fore when McTaggart (1908) proposed that all events could be ordered in time using either one of his two 'series of time'. The debate has continued ever since, and most

[1] These theories and others are discussed in more detail in the section, 'The Paradoxes of Backwards Time Travel' which begins on page 62 of Chapter Three.

[2] Most (but not all) cosmological models are globally hyperbolic and cannot accommodate CTCs.

[3] Oedipus unwittingly fulfils a prophecy that foretells he will kill his father and marry his mother.

(but not all) commentators now side with McTaggart's B-series of time, but dispute his conclusion that time must be unreal.[1]

There is also an ongoing debate in philosophy about time travel, and Richmond (2003, p. 297) notes:

> For some years, the topic of time travel has prompted interesting philosophical discussions. However, despite decades' worth of defences and rebuttals, there isn't yet consensus as to whether or not time travel is possible, or, if possible, of what kind of possibility. Some say that logic forbids time travel, while others maintain that metaphysical necessities or physical contingencies prevent it. Yet others hold that, for all we know, time travel might not only be possible but actually attained.

Zeh (2001, pp. 4-5) notes, "classes of phenomena characterizing a direction in time have been called *arrows of time.*" The most important arrows of time, he says, are: radiation, thermodynamics, evolution, quantum mechanical measurement, exponential decay, and gravity.

Directions of time

Scientists working in different fields have to use different models of time from each other. For example, in the area of relativistic physics, at the fundamental level, there is timelessness because time is wrapped up in the space-time continuum. In the Newtonian world and even the quantum world, time is a physical parameter that is used to track change. The equations used to describe these worlds work equally well in reverse; there is nothing about them that says they can only work in one direction. However, when we apply these equations to our macroscopic world, time has only one direction – we live in a world of increasing entropy.[2] [3]

Physicists and philosophers have long postulated reasons for why time appears to be asymmetric, and therefore only able to have one direction when "the laws of science do not distinguish between the forward and backward directions of time" (Hawking, 2008, pp. 392-393). The problem is explained by Zeh (2001, p. 1) in his book, *The Physical Basis of the Direction of Time.*

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[1] The A and B theories of time are discussed more fully on page 42 of Chapter Three.

[2] Entropy is the quantitative measure of disorder in a system. This hugely controversial topic is discussed more fully in the section 'The arrow of time' on page 50 of Chapter Three.

[3] There is also the case of the exception of CP symmetry violation, and therefore by the CPT theorem, time reversal asymmetry in the weak interaction, (where C is charge, P is parity and T is time).

> If physics is to justify the hypothesis that its laws control everything that happens in Nature, it should be able to explain (or consistently describe) this fundamental asymmetry, which defines what may be called a *direction in time* or even …a direction *of* time. Surprisingly, the very laws of Nature are in pronounced contrast to this fundamental asymmetry: they are essentially symmetric under time reversal. It is this discrepancy that defines the enigma of the direction of time.

Philosopher Price (1996, p. 16) argues that if we had an atemporal viewpoint taken from outside of time, it would reveal the true symmetrical nature of time as implied by the block universe.[1] In other words, there only *appears* to be an arrow of time to observers because they exist in the dimension of time.

Psychologists even have trouble agreeing about the perception of time. Woodrow (1951, p. 1224) states, "the data in the literature of time perception indicate the conflicting nature of the findings of different experimenters." Gibson (1975) holds that the perception of time is an insoluble problem; there is no such thing as the perception of time, but only the perception of events.

There is a difference between the alternate conceptions mentioned thus far and misconceptions in science, which for the public, further complicate the picture. For example, there are still those that refuse to accept that forwards time travel is possible even though Einstein's 1905 theory of special relativity shows that the faster a vehicle moves, the more slowly it ages.[2] From around the start of the last century, scientific discussions about forwards time travel with rockets were able to take place. Many scientists of the day were shocked that their cherished Newtonian time had been proven to be inaccurate, and it took a long time to convince them that this was so. Even though this theory has since been proven experimentally, there are still those who find it hard to believe, as Nahin (1993, p. 26) points out:

> Some modern philosophers … are still not quite sure about this particular way of traveling into the future and have confused it with simply being asleep or being frozen…. The Victorian shock over the relativity of time has obviously not yet totally disappeared…. For example, one philosopher – Mellor (1981) goes on to declare … All in all, real forward time travel is … really only an overly grand description of processes slowing down or stopping.

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[1] The block universe is discussed more fully in the section, 'The block universe theory of time' on page 44 of Chapter Three.

[2] This is known as 'time dilation' and how this may be interpreted as forwards time travel is discussed more fully in the section, 'Time dilation and relativity' on page 53 of Chapter Three.

Pickover (1999b) adds, “For centuries, these questions have intrigued mystics, philosophers, and scientists, and the subject of time has been central to the world's many diverse religions and cultures.” In his book (1999a, p. xvii), he writes, “Is time real? Does it flow in one direction only? Does it have a beginning or an end? What is eternity? None of these questions can be answered to scientists' satisfaction.”

As shown, neither physicists, philosophers, nor psychologists can agree on the nature of time. These unresolved issues are then magnified by the introduction of the topic of time travel, where there is much uncertainty about whether time travel is possible and what would happen if it were. With no universally accepted understanding of what constitutes time, various models of time currently exist, reflected in people’s personal perceptions and their philosophical position. It may not be possible to discover which of these models is a true representation of time even if the technology of time travel has been developed, or until we have a full theory of quantum gravity.[1]

Therefore, if scientists and philosophers cannot agree on a universal model of time, then how can filmmakers decide which models of time to use in their films? And if the filmmakers do not know which models of time are accurate, then what chance do the movie-going public have of separating fact, speculation and fiction?

Time travel in the public eye

The topic of time travel has been placed in the public domain by the high number of television shows, plays, novels, computer games, and particularly films in the last two decades.[2] However, the unresolved issues and controversies in science are not in the public domain, so what the public accesses is perceived as science fiction, loosely based on these issues.

Films involving time travel are also important because new science can come from science fiction as explained by Nahin (1993, p. ix).

> Smart physicists seek insights everywhere, including from clever science fiction writers, who long ago began probing seriously the logical consequences that would ensue if the laws of physics permitted time travel. For example, Igor Novikov’s Principle of Self Consistency has its roots in science fiction.

[1] Quantum gravity is discussed more fully in the section ‘A universe without time’ on page 51 of Chapter Three.

[2] The rising trend in the number of time travel films released is discussed in the ‘Results and Analysis’ section on page 91 of Chapter Four.

When Carl Sagan was writing his novel *Contact*, he asked his friend, physicist Kip Thorne, how he could transport a person to a distant star and back with virtually no time having passed on Earth. By considering this question, "Thorne revitalized the whole modern field of the study of wormholes" (Palmer, 1997).

In the medium of film, the answers to many of the unanswered questions about time travel frame the underlying hypothesis around which the narrative is built. An analysis of the narrative therefore provides an opportunity for deducing the model of time travel employed in each film, which then enables a comparison of the models with conventional scientific ideas and with the public perception of time travel.

The point of this research is to uncover the different models of time travel used by filmmakers in order to discover if they can be used to construct a comprehensive set of models about time travel and its consequences. Scientists, philosophers, filmmakers and the public could then use these models to further their understanding about time travel, its consequences, and how it is being communicated.

Aims of the Study

My thesis is about identifying the ways in which the science of time travel is presented to the public through the medium of feature films, their connection with the public perception of time travel, and how they can contribute to the construction of a comprehensive set of models about time travel and its consequences.

My specific aims are to identify the different theories and ideas about time travel produced by science and philosophy researchers; to uncover the different models of time travel used in films; and to determine which personal models of time travel are being used by members of the movie-going public. An additional aim is to find out how the beliefs of the movie-going public who have studied the physics or philosophy of time at an academic level differ from those who have not.

Research Questions

The main research question of this thesis that emerged from my aims is: 'Can the implicit models of time travel used in films be used to construct a comprehensive set of models about time travel and its consequences?' There are also three sub-questions:

1. What theories and ideas have researchers from science and philosophy produced about time travel?

2. What models of time travel can be constructed from films?

3. How do these models of time travel compare with the personal models used by members of the movie-going public?

Method

Three studies are used to address the research questions.

1. Identifying and collating the different theories and ideas that researchers from science and philosophy have produced about time travel.
2. Sourcing and analysing more than 100 films involving time travel to produce a detailed review - not of the plot, but of how temporal phenomena are treated in the plot of the film in order to identify the model of time travel being used in each film.
3. Employing focus groups interviews with members of the movie-going public to identify their personal models of time travel.

Figure 1 shows how each of the studies relates back to the different aspects of science communication.

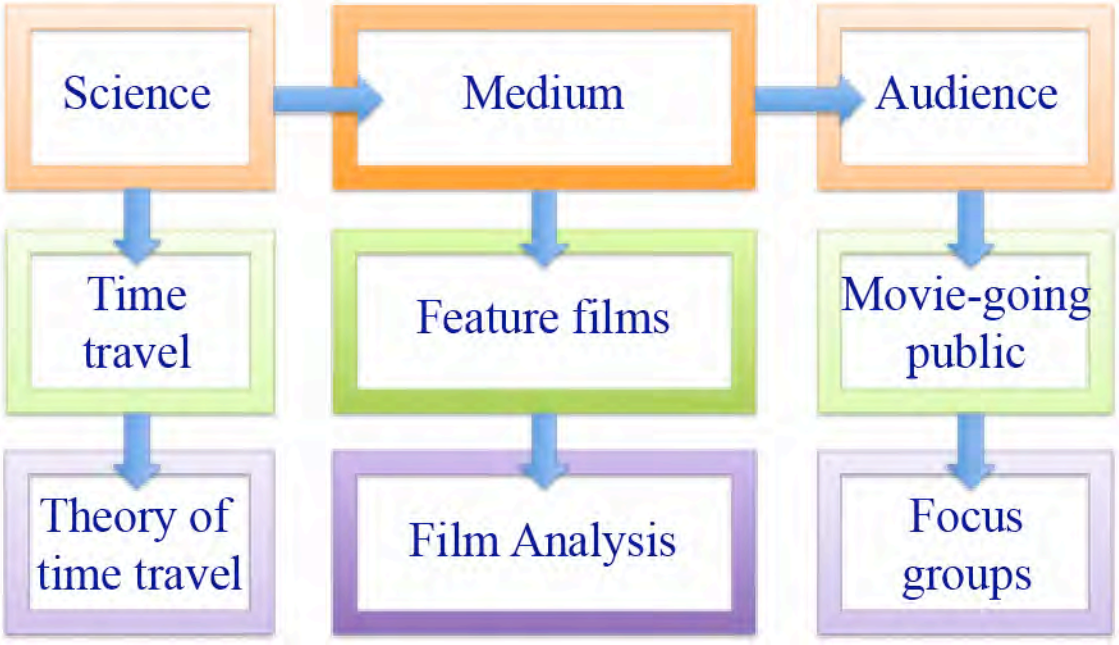

Figure 1: The method used to achieve each of the three subsidiary aims of this thesis

The results of these three studies are then synthesised to further develop the models of time travel into a complete comprehensive set that incorporates the views of scientists,

philosophers and the public, thus contributing to the construction of models about time travel and its consequences.

Scope

The main part of this thesis is the study of time travel films. The scope of this study had to be sufficiently large to encompass a wide range of films, but narrow enough to make it manageable. This was a study of films as opposed to other forms of fiction such as television shows, plays, novels, and computer games. In order to reduce the number of films to a manageable level, I chose to review only the films that ran for at least 80 minutes, which ruled out hundreds of short films that involved time travel. There were hundreds of films involving time travel that fit this criterion, but they were not all readily available. I chose a target sample size of 100 films to review and analyse because I felt this would give me a large enough data set from which to draw meaningful conclusions.

The focus group study was an exploratory study, as the main part of this thesis was the film analysis. Two of the focus groups were made up of participants who had not studied the physics or philosophy of time at an academic level, while another focus group was targeted at those who had. The participants of all the groups were required to have previously watched some time travel films.

Thesis Overview

This thesis is comprised of seven chapters.

Chapter Two contains the literature review, which places the academic discipline of Science Communication in context, and locates this thesis within the discipline. I reviewed the literature in which time travel films have been discussed from an academic perspective. Public beliefs about time and time travel are discussed including circular and linear time, as is the influence of time travel fiction on popular culture. The unresolved issues regarding models of time travel are identified, which leads to the formation of my research questions.

Chapter Three contains the first study of this thesis, the main aim of which is to identify the different theories and ideas about time and time travel produced by researchers in science and philosophy. The purpose of this is so that in Chapter Six they can be

compared with the models of time travel used by filmmakers and the personal models of time travel used by the movie-going public.

Chapter Four contains the second study, which is an investigation into the models of time travel used in films. The aims of this chapter are to create a list of time travel films and to review them in order for them to be categorised in relation to the different ways they portray time so as to uncover a set of models of time travel used in films. A further aim is to identify if there were any models of time travel not used by filmmakers.

Chapter Five contains the third study, in which I conducted three focus groups and an interview with a filmmaker to determine whether members of the movie-going public could relate to the models of time travel that I had identified in Chapter Four. Two of the focus groups were conducted with members of the public who had not studied time at an academic level, and the other was with conducted with those who had. The findings helped me to modify the structure of these models and to identify any new models of time travel that I had not previously considered. They also allowed me to discover which of these models most closely represented each participant's personal model of time travel.

In Chapter Six, I synthesise the findings of the film study from Chapter Four with the findings of the focus groups from Chapter Five and with the theories of time contained in Chapter Three to develop a comprehensive set of models of time travel. I then relate this set of models back to the film study to establish which models were used in film and which were not. I also relate it back to the beliefs and opinions stated by the movie-going public to establish which of my models matched their personal models of time travel, and which did not.

In Chapter Seven, I draw conclusions about how the findings of this thesis helped me to construct a comprehensive set of models about time travel and its consequences. I also discuss the contribution that this study has made, as well as its limitations and I make recommendations for further study.

The chapters of this thesis are summarised in Figure 2, which is a diagrammatic representation of how they relate to one another.

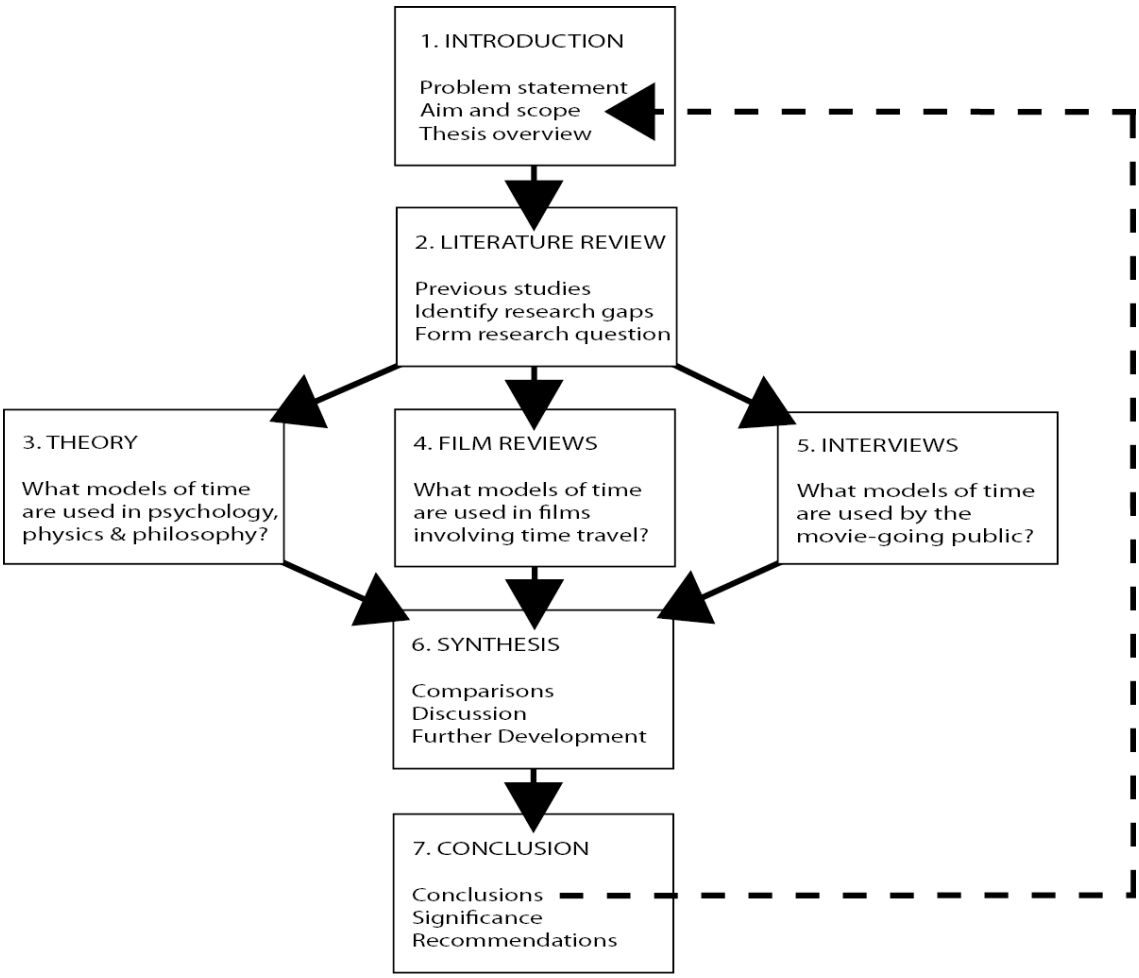

Figure 2: How the chapters of this thesis relate to one another

The following chapter places this research in a disciplinary context, highlighting key themes and unresolved issues. It summarises the research from film studies, the social sciences, and philosophy in the area of science fiction films and in particular films involving time travel. It also covers the public perception of science, as well as public beliefs about time travel including how time travel fiction has influenced them.

CHAPTER TWO: LITERATURE REVIEW

> *We all have our time machines. Some take us back, they're called memories. Some take us forward, they're called dreams.*
>
> - Jeremy Irons, actor[1]

The aim of this chapter is to place my research in a disciplinary context by looking at a short history of the discipline of science communication, at why good science communication is important, and at how science is communicated to the public.

I review the research conducted about science fiction films in the areas of science education and science misconceptions. I also address the academic literature regarding time travel films in the areas of philosophy, sociology, and film studies. I look at the influence that time travel films have had on public beliefs about time and also how different cultures can affect these beliefs. Finally, I review the different types of timelines that film critics and fans have used to describe how time travel works in various films.

Key themes and unresolved issues are then highlighted to reveal the main research question of this thesis: 'Can the implicit models of time travel used in time travel films be used to construct a comprehensive set of models about time travel and its consequences?'

Science Communication

A short history of the discipline

"Both in Britain and the United States the public says it is more interested in science than (for example) sport" (Durant, Evans, & Thomas, 1989, p. 11). Nevertheless an assumption was made in this influential paper that a public existed whose understanding of science was lacking. This became known as the 'Deficit Model', which was based on the premise that it was important for the public understanding of science to be improved; this argument could be split into five sections: economic, utilitarian, democratic, cultural, and social.

[1] ThinkExist. (2010).

- The economic argument is about how scientific innovation can benefit the economy, and is the main driving force behind most scientific research today. An example would be how nanotechnology can make products smaller, better and cheaper.
- "The utilitarian argument is … the view that the public should be scientifically aware because of the way the community uses science" (Stocklmayer, Gore, & Bryant, 2001, p. ix). One current example would be the consumption of genetically modified food. Future technologies that are still being developed could become utilitarian examples such as the cryogenic freezing of living organisms that would allow for time travel to the future. Both examples have moral, ethical and health implications.
- The democratic argument is about how public policy decisions involving science "can only be genuinely democratic if they arise out of informed public debate" (Durant, et al., 1989, p. 11). When people have been misinformed by poor science communication, public misconceptions of science can be created, which could seriously hinder any scientific debate.
- The cultural argument is that "the best science is like high art, worth appreciating for its own sake and not necessarily because it brings an immediate benefit" (Stocklmayer, et al., 2001, p. ix). For example, we may never possess the technology to build wormholes in the spacetime fabric, but it does not stop scientists from creating theoretical models for them.
- The social argument is that the public understanding of science will "serve to enhance social cohesion" (Stocklmayer, et al., 2001, p. x). The more that the public are aware of an aspect of science, the more meaningful their conversations on the topic will be.

These arguments were all used in the 1980s and 1990s to highlight important areas where the public's understanding of science was lacking. The UK government sought to remedy this situation by helping those interested in science to increase their knowledge. The problem with this policy was that it was preaching to the converted. Scientists were not reaching the community as a whole, and the goals of the British government were

not being achieved, based on the evidence that the uptake of science in schools continued to decrease.

The final report of the Wolfendale Committee (1995) reviewed the contribution of scientists and engineers to the public understanding of science, engineering and technology, and it stated, “In a changing world, the maintenance of research support, and hopefully its enhancement, and also the increased take-up of science and engineering subjects by people of all ages, will depend on public appreciation of science and engineering and their practitioners.” Five years later a report from the British House of Lords (2000, p. 140) stated:

> [T]he expression "public understanding of science" may not be the most appropriate label…. It is argued that the words imply a condescending assumption that any difficulties in the relationship between science and society are due entirely to ignorance and misunderstanding on the part of the public; and that, with enough public-understanding activity, the public can be brought to greater knowledge, whereupon all will be well.

It suggested abandoning the term ‘public understanding of science’ (PUS) and replacing it with another term, which inferred installing a sense of ‘needing to know’ in the community, particularly for those that did not yet have an interest in science. Various terms have been used since; the most commonly used term in Australia is ‘public awareness of science’ (PAS).

This change eventually led to the separation of science communication with its informal learning and outreach activities from the discipline of science education. A blurring of the two does still sometimes occur with PUS practices still used in some science communication activities, and the PAS approach often used as an effective tool in science education.

> Debates on science communication have shifted from explaining science to the public to discussing science with the public. Therefore, much of the research in the area of science communication explores the structure, meanings, and implications of the public communication of science, technology and medicine (PCSTM). This means examining the contexts in which communication about science occurs, the motivations of and constraints on people involved in producing information about science for non-professional audiences, and the overall functions of public communication of science and technology.
>
> (The University of Manchester, n.d.)

Bryant (2003, p. 357) defines science communication as the “processes by which scientific culture and knowledge is incorporated into the common culture.” However, the discipline of science communication is not just about communicating science to the

public, it also covers communicating it to areas that are not in the public domain. For example, scientists successfully communicate their science to each other, most commonly through peer-reviewed journals, or by giving talks and/or presenting posters at conferences. However, the area of science communication where this thesis is located is the area where science is communicated to the public.

Communicating science to the public

In order to reach the public, scientists often communicate their science by giving public lectures, or by giving interviews to television, radio and/or the press. Companies and research institutions often have their own marketing and communication teams that use a variety of ways to promote and explain their organisation's science to the public. These can include public exhibitions, brochures, posters, competitions, school visits, and new media such as websites, podcasts, vodcasts, online video clips, blogs, as well as social media. Popular science documentaries are often made for television that either promote an area of scientific research or question it, but it seems most people get their science from television news stories. "Three-quarters of respondents [to an Australian survey] said they were interested in science, with most receiving their information from television news stories. Only 6 per cent sourced their information from science magazines and 3 per cent from science centres" (Osborne, 2011).

Some scientists write popular science books as way of promoting and popularising their brand of science. Ben-Ari (1999, p. 819) comments, "books written by scientists for a popular audience provide a means of access to hidden worlds." He goes on to suggest that the success of *A Brief History of Time,* a cosmology book written by physicist Stephen Hawking, "has led to an increased awareness of the significant audience for serious science books that are written by scientists, but are accessible to a broader readership."[1] Meyer (2005, p. 7) writes, "the audience for a popular science book can include those with a vocational interest in the subject, or scientists from another discipline." This can be an important tool in the area of cross-disciplinary research. "Writing popular science books can be a useful way for experts in a multi-disciplinary field to communicate with each other at a level all can understand" (Mantell, 1995). Examples of well-known popular science books written by scientists are *The Selfish*

[1] More than 9 million copies sold worldwide since its publication in 1988 by Bantam, London.

Gene by biologist Richard Dawkins, *The Emperor's New Mind* by mathematician Roger Penrose, and *Hyperspace* by theoretical physicist Michio Kaku.

String theorist Brian Greene hosted *The Elegant Universe*, an Emmy Award winning three-part television documentary, which was adapted from his popular science book of the same title. Then there is the scientist Sir David Attenborough, who has been writing and presenting a range of natural history documentaries at the BBC (British Broadcasting Corporation) for more than 50 years.

Scientists sometimes venture into the area of science fiction such as astronomer Carl Sagan, who wrote the best-selling novel *Contact* in 1985. However, most science fiction is not written by scientists, but rather by authors or scriptwriters. Philip K. Dick is an author of many science fiction short stories and novels, several of which involved time travel. There are also the scriptwriters of science fiction television series such as *Star Trek* or *Doctor Who,* about which Orthia (2010, p. 2) notes, "When first produced in 1963, one of the show's original goals was to teach science to children." She also notes (p. v) that:

> If communication products such as television series can influence people's relationships with science in terms of their career choices, belief systems and feelings of ownership over science, then it is important for science communicators to understand what television series are saying about science.

Scriptwriters, who communicate science through their science fiction films, often use scientists as consultants. "Scientists have become increasingly involved in the production of movies and television shows" (The University of Manchester, n.d.). So, as I have shown, there are many ways that science is being communicated to the public; however, in this thesis I am going to focus on how it is communicated through film.

Science Fiction Films

"Stanley Kubrick's *2001: A Space Odyssey*, released in 1968, is perhaps the most scientifically accurate film ever produced," says Kirby (2011a) who goes on to offer the following reason: "Kubrick's scientific verisimilitude in 2001 came courtesy of his science consultants—including two former NASA scientists—and the more than sixty-five companies, research organizations, and government agencies that offered technical advice." Galison (as cited in ibid.) suggests that one of the reasons scientists get involved with a film is because, "scientists can alter the public status of their fields and gain a powerful hand in articulating visions of how their own fields might work."

When a science fiction story or theme is adapted for the big screen, it allows the science it contains to reach and hence potentially influence an even larger section of the general public. Kirby states, "Scholars have begun to recognize cinema's role in the public communication of science and technology and its importance in the public understanding of science" (2008, p. 41).

For example, both of the television series *Star Trek* and *Doctor Who* have been adapted several times for the big screen, as was Carl Sagan's aforementioned novel, which became the film *Contact* (1997).[1] Also, "eight of Philip K. Dick's novels or short stories have made their way to the big screen" (Philip K. Dick Trust, 2003-2010), several of which involved time travel.

Science fiction film as an educational tool

Another use for science fiction films is for educational purposes. Dubeck, Moshier, & Boss (cited in Osborne, 2011) wrote a book that "provides basic physics and biology instruction using scenes from popular science fiction films as examples of the concepts discussed." There have been many papers written since then about the growing use of science fiction films in the classroom as a way of getting students interested in physics. For example, Dark (1994) argues that movies are a *visual* learning aid and that "introductory physics students show a strong interest in participating in movie-related activities compared to standard group problem-solving sessions." In an article in *Science in School,* Al-Khalili (2005) from the University of Surrey explains that he uses time travel films in class to introduce some of the ideas behind Einstein's theories of relativity. Papacosta (2009) cites the example of *2010: The year we made contact* (1984) as a film that "is based on accurate and realistic concepts of science and technology." He gets his students to complete a questionnaire on the physics principles and different types of technology incorporated in the film.

Time travel films have also been used to promote philosophy: a 2007 undergraduate course 'Science Fiction and Philosophy: From Time Travel to Superintelligence' grew out of the course designer, Schneider's "quest for a compelling way to introduce students to philosophy" (ibid., 2003, p. 57). This course led to her publishing a book of the same title (Zeeberg, 2009) that uses time travel films to discuss the nature of space and time.

[1] This film is reviewed on page 260 of Appendix I.

Bixler (2007, p. 337) uses science fiction films in her biology classes to "encourage higher-level thinking (application, evaluation) about some of the more complicated issues in evolutionary theory." She also used the classic science fiction film, *The Time Machine* (1963) to illustrate the concept of speculation" (p. 338).

These are just some of the examples of how science fiction films can be used in a classroom setting as a way of engaging students in science, and it can be done either by discussing the accurate science in the film, or by highlighting the science misconceptions that exist within them.

Science misconceptions in science-fiction films

The scientific culture and knowledge embedded in science fiction films is not always an accurate reflection of the original science because the very nature of science fiction films is that some of the science has to be speculative, such as time travel. However, many filmmakers try to get the current science as accurate as they can. Kirby (2011b) notes, "It may surprise people to learn that most contemporary filmmakers believe that scientific integrity is important. In fact, it would be surprising today to have a film production with science content which did not bring in a science consultant."

Perkowitz (as cited in Sample, 2010) proposes a possible solution to the problem of scientific misconceptions being passed onto the public by creating a set of guidelines for Hollywood:

> Science fiction movies should be allowed only one major transgression of the laws of physics. [His] proposals are intended to curb the film industry's worst abuses of science by confining scriptwriters to plotlines that embrace the suspension of disbelief, but stop short of demanding it in every scene.

However, if you had a film that was full of good physics but had just one violation of the laws of physics buried in the middle – as Perkowitz desires – the risk is that the audience might not think the film was science fiction, which could then create a misconception for them about physics.

Williams (as quoted by Phillips, 2010) disagrees with Perkowitz by saying that it is "ludicrous that scientists, of all people, would attempt to impose their view of what is possible, especially when there have been spectacular instances of the seemingly impossible suddenly becoming possible." Phillips gives an example about the invisibility cloak. "It is every child's dream to vanish into thin air like Harry Potter. In

2008 scientists in the US brought that dream closer to reality when they invented a material that makes light bend away from it."

Barriga, Shapiro, and Fernandez (2010, p. 5) propose, "Mistaken facts learned from movies, could have consequences for public opinion regarding natural phenomena, attitudes toward scientists, and priorities of science research." Allday (2003, p. 27) questions how much the audience notice the good and bad physics in popular science fiction films, and he suggests that if viewers absorb most of the physics without thinking about it, this could go on to create misconceptions for them about the laws of physics. A mixture of good science (fact) with bad science (fiction) in the same film is not always a good recipe. Barnett et al. (2006, p. 179) state that "Researchers who have investigated the public understanding of science have argued that fictional cinema and television have proven to be particularly effective at blurring the distinction between fact and fiction."

Barriga, et al., (2010, p. 4) note that:

> Misinformation is more likely than correct information to be remembered as correct information over time (Marsh et al., 2003), and to be attributed to a knowledgeable source, when it was really presented as a fictional narrative (Frost, Ingraham, & Wilson, 2002). People appear to misattribute the origin of the new information to a more reliable source and "forget" its fictional source.

A survey called 'Fact or Fiction' was conducted as part of the Australian National Science Week 2011, and it asked people whether eight scientific technologies seen in feature films, such as light sabres, invisibility cloaks or hover boards, were science fact or fiction (Osborne, 2011). One finding of this survey was that almost half of the respondents believe humans can be frozen and thawed back to life, despite the fact that this type of forward time travel technology is not yet available. Dowler (cited in Osborne, 2011) commented, "This survey has confirmed that willingly or not, we believe in science fiction movies more than we realise."

Several books have been written listing and discussing the various misconceptions present in science fiction films such as Weiner (2007), who attempts to "deconstruct, demystify, and debunk action sequences from Hollywood films through the use of scientific explanations." Rogers (2007) discusses the importance of knowing when and when not to alter the physics in a film. He also examines the accuracy of the physics of

time travel, as does Perkowitz (2007, p. 4), who discusses Hollywood films that have "spacecraft that travel faster than light, which the theory of relativity forbids."

Rather than worrying about the *accuracy* of science in film, Kirby (2011b) encourages viewers to ask if the science in a film seems plausible:

> The distinction between plausibility and accuracy is crucial to appreciating science in cinema. Plausibility directly relates to maintaining an audience's suspension of disbelief, and thus, their willingness to buy into a film's fictional conceits that allows them to enjoy the parts of the film that are not about science. Therefore, the science in movies does not have to be "accurate" to render fantastical events as plausible.

So maybe the best films are not the ones with the most accurate science, rather they are the ones that use plausible science to add to the film's entertainment value.

The literature about science in science fiction films is growing; however, Kirby (2008, p. 67) notes that it is not emerging from a single field: "These works draw upon a wide variety of approaches and methodologies from numerous disciplines including communication, sociology, history, film studies, cultural studies, literature, and science fiction studies."

Time travel in film

The social and philosophical aspects of time travel in film have been discussed by many authors: Kimball (2002) comments in his film studies article that "time travel, in short, folds all temporal moments into one another; that is, it enables science fiction films to present the past, the present, and the future simultaneously." Martin-Jones (2007) discusses how "several South Korean films deployed time travel narratives to explore the impact of compressed modernity on national identity."

The cultural meaning of several time travel films is discussed by Sobchack (1987, p. 248), in particular the "regressive and circular time travel plot" of *The Terminator* (1984). Penley (1986, p. 71) explains, "This sort of story is called a time-loop paradox because cause and effect are not only reversed but put into a circle: the later events are caused by the earlier events, and the earlier by the later." Dimitrakaki & Tsiantis (2002, p. 216) argue that "the popularity and appeal of the time-loop paradox [in film] has been viewed as a fulfilment of the Freudian 'primal scene' fantasy." Jancovich (1992, p. 3) discusses how Penley relates the narrative of the film to Freud's discussion of the primal scene fantasy: the fantasy of being present at one's own conception. He states:

> In the case of *The Terminator*, she focuses on the narrative's use of a "time-loop paradox," a paradox in which the past and future presuppose--or cause--one another. For Penley, this form of narrative usually involves an incestuous relationship in which the protagonist comes to be its own parent.

Time loops are now appearing more regularly in the plots of time travel films, and more recently, time travel stories and films have started to include such concepts as parallel worlds and alternate histories, which come from certain interpretations of quantum physics. Hunter (2004) states, "Indeed, the sometimes counter-intuitive principles and effects of quantum theory have invigorated time travel stories." In his PhD dissertation, Tryon (2002) explores the relationship between "temporality and subjectivity through the genre of time travel cinema," and also looks at the "constructions of subjectivity in alternate-reality films." The narratives of four different films involving parallel worlds are compared by Bordel (2002), who comments that they "are built not upon philosophy or physics but folk psychology, the ordinary processes we use to make sense of the world." He also notes that "instead of the infinite, radically diverse set of alternatives evoked by the parallel-universes conception, [these films] have a set narrow both in number and in core conditions."

So, as can be seen, when unfamiliar or counter-intuitive concepts from physics such as time loops and parallel worlds begin to appear in film, this becomes part of the diversity of ways by which time travel is communicated to the public.

The influence of time travel films

It is not known how much influence time travel fiction has had on the public's perception of time, but I suggest it has shaped it to some degree. Barriga, Shapiro, and Fernandez (2010, pp. 3-4) comment, "Although the literature about information learning from fiction is not extensive, there are indications that fictional genres, such as stories, novels, or movies, can also affect real-world beliefs and knowledge."

As mentioned in Chapter One, three very popular novels involving time travel were first published in the 19th century: Charles Dickens' *A Christmas Carol* (1843), Mark Twain's *A Connecticut Yankee In King Arthur's Court* (1889), and H.G. Wells' *The Time Machine* (1895). Other time travel stories had appeared before this, but had been nowhere near as popular. Nahin (1993, p. 22) explains that early time travel machine stories always had a limited readership, "because most Victorians thought the notion of time travel was simply outrageous, such stories generally excited a sceptical response."

He also notes that nearly twenty years after *The Time Machine* was published, Walter Pitkin, a university professor of journalism, criticized Wellsian time travel as being "a frivolous example drawn from contemporary fiction." However, as the concepts surrounding the physics of special relativity became better known, the idea of time travel slowly became less fantastical to the public. Bigelow (2001, p. 81) states:

> [P]remature births of the time travel idea fell on stony ground – the idea just didn't *stick* – until there was a wide enough public who were prepared for the radical spatialization of time. When people were ready for it, however, the time travel idea hit popular culture the way rabbits hit Australia. There has been a pandemic of them ever since.

Hunter (2004) agrees, "Time travel stories have been a staple of the science fiction genre for the past century."

Soon after the arrival of the medium of film, the adaptation of time travel stories to the big screen began. For example, a film adaptation was released for each of the three novels mentioned above, and *A Connecticut Yankee In King Arthur's Court* (1949) and *The Time Machine* (1960), were both big box office successes. Other film adaptations of the these stories have since been released, and although *A Christmas Carol* (1938) was not a big box office success, Bigelow (2001) notes, "throughout the 1960s this was the version most frequently shown on television." The popularity of time travel stories in film has increased to the point that film is now a medium in which "time travel is an accepted norm," according to Benyahia, Gaffney, & White (2009, p. 5).

So it seems that filmmakers help to bring the concepts surrounding time travel into the imagination of the movie-going public, and Kirby (2011a) goes even further by suggesting, "Depictions of science in popular films can … contribute to scientific controversies, and even stir citizens into political action."

Discussions about time travel and the philosophy of science can also be stimulated by filmmakers through their films. For example, Isaacs (1973, p. 129) notes that the time travel film *Slaughterhouse Five* (1972) has "science fiction that deals with the topic of free will versus fatalism and a related philosophical issue of the nature of time." Deeper discussions about time travel by fans and filmmakers can often take place on a film's official website. These can allow for a better understanding of the plot and/or the scientific concepts around which a film is based. Some films such as *Donnie Darko* (2001) that have complex time travel plots are difficult to fully comprehend without the

aid of the companion website. Booth (2008, p. 399) declares that the website of this film serves "as both an extension of and an explication of [the film's] plot."

As mentioned previously in this chapter, it is not just the filmmakers and fans that shape how the public understands science; the science consultants also have a big role to play. Stentz (2011) writes, "In the gap between science fact and science fiction stands the motion picture and television science consultant. [They shape] how film and television makers depict science – depictions which in turn shape how science is understood by the public at large."

Science fiction films can influence scientific research as well as public opinion. Dowler (cited in Osborne, 2011) notes, "Science [fiction] films can be very inspirational to scientists and the general public, getting more people interested in science and setting the bar for the types of technology we would like in the future." Kirby (2011a) agrees, "Depictions of science in popular films can promote research agendas [and] stimulate technological development." An example of this is given by Baker (as quoted in Phillips, 2010), "episodes of Star Trek prompted the invention of many modern gadgets … translators, automatic doors, voice recognition and portable data storage devices were all featured in the series." However, one seemingly impossible plot device used in several *Star Trek* films that has not yet become a reality is backwards time travel.

I have shown how films can help to shape public understanding, alter public opinion, or stimulate deep public discussions about time travel. One tool often used in such discussions or explanations about time travel is the timeline diagram.

Timelines diagrams

The dictionary definition of timeline is, "Line drawn on a suitable scale (days, months, years, centuries, eons) on which key historical, planned, or projected events and periods are marked in the sequence of their occurrence" ("timeline,"). It is also a type of chronology, "a sequence of related events arranged in chronological order and displayed along a line (usually drawn left to right or top to bottom)" ("Chronology,").

A timeline can take the form of a list or a diagram with a line or lines that represent a sequence of events, and it is not always drawn to scale. In order to help explain the plot in a time travel film, a diagram can be used to show how the timeline is being replaced (or not) when each character in the film arrives at a new point in time. It is useful for

showing when a timeline splits such that a new version of the timeline exists in parallel to the original. A timeline diagram can also be used to show the time traveller's point of departure and their arrival at a different point on the timeline.

Timeline diagrams are used by fans of time travel films to explain their theories about what is happening with the timeline in a particular film. Filmmakers sometimes have their characters use them in the film, as they can help to explain to the audience what is happening. For example, Figure 3 shows Doc Brown in the second film of the *Back to the Future* trilogy drawing a timeline diagram to help him explain to Marty why an alternate 1985 has been created. The horizontal line is the original timeline, the curved line represents Old Biff's journey back through time, and the diagonal line shows the new timeline that has been created as a result of the changes made by Old Biff to the past.

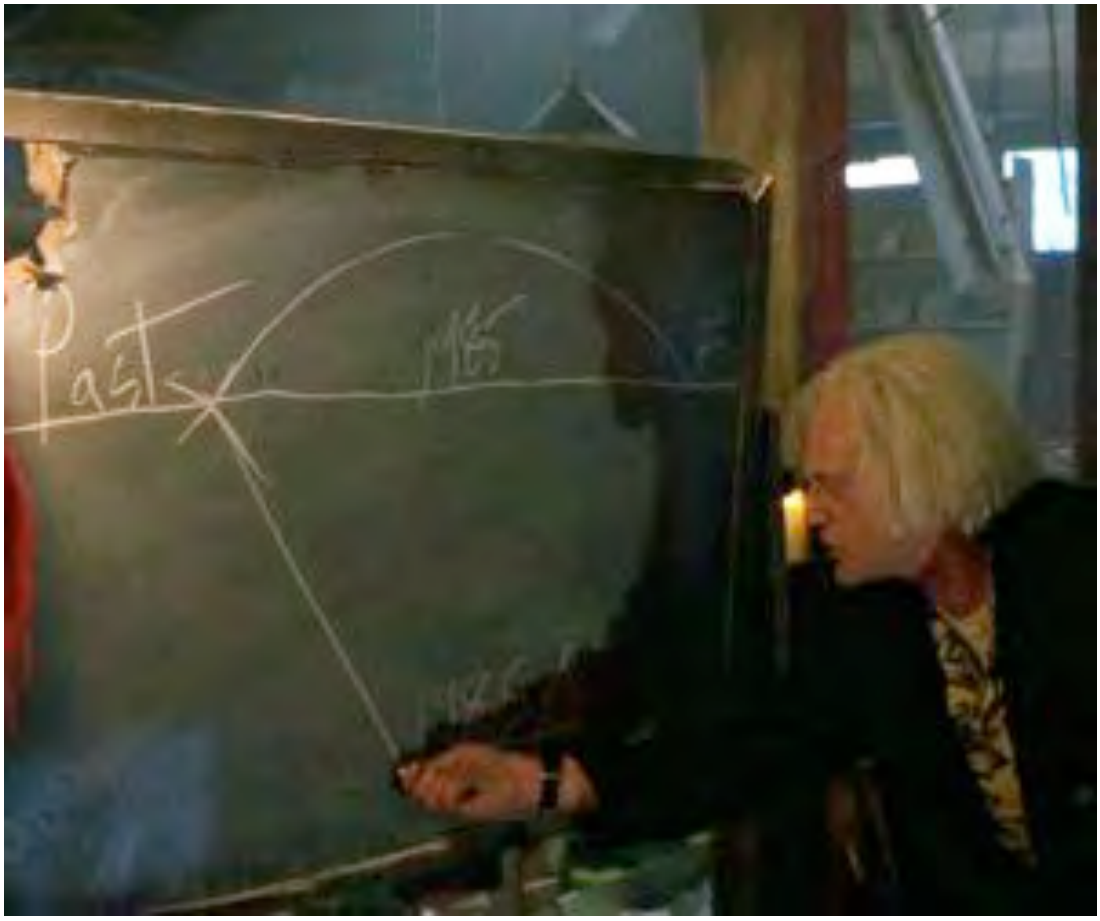

Figure 3: The timeline diagram being drawn in *Back to the Future Part II* (1989)[1]

[1] Silver (2009).

Following are several different examples of timelines that were created by film fans to help explain their understanding of the plot of a time travel film, a television show, or a series of them.

The first example is shown in Figure 4, and it is a partial list of the sequence of events that takes place in the time travel film *Primer* (2004).

Monday

5:45 am – Abe0 starts the timer for the failsafe machine (box F0).
6:00 am – Box F0 activates. Aaron3 exits with boxes A1 and B1.
6:00 am – 9:00 am – Aaron3 sets up his own failsafe A1 and replaces Abe's failsafe with B1. Aaron3 starts the timers on the new failsafes and no one exits them. ***Aaron3 drugs Aaron0, creating a double. HoodedAaron3 stuffs OriginalAaron0 in the attic.*** Aaron3 begins recording events, wearing headphones so that the recording will match when he must wear the headphones to hear them.
8:45 am – Abe0 starts the timer for the first testable box (box A0).
9:00 am – Box A0 activates. Abe1 exits the box.
8:45 am – 2:45 pm – Abe0 drives to and stays at a hotel in Russelfield. **Abe1 finds Aaron3 at the bench and explains what he has found. Aaron3 is wearing his headphones, but isn't listening to anything.**
3:00 pm – **Abe0 enters box A0. Aaron3 and Abe1 watch from the field.**
3:00 pm – 9:00 pm – Aaron3 and Abe1 make another box (box B0).
9:00 pm – 12:00 am – Robert's birthday party is interrupted by Rachel's ex-boyfriend and his shotgun. Aaron3 attends the party and "rushes" him. Everyone calls him a hero, but Rachel's ex-boyfriend is not arrested.

Tuesday

8:45 am – Aaron3 and Abe1 start the timers for the boxes A0 and B0.
9:00 am – Boxes A0 and B0 activate. No one exits.
8:45 am – 2:45 pm – **Aaron3 and Abe1 drive to and stay at a hotel in Russelfield.** They research stocks at a library.
3:00 pm – **Aaron3 and Abe1 enter boxes A0 and B0.** (This creates Timeline 5).

;----------
; Timeline 5
;----------

Monday – same as Timeline 4

Tuesday

8:45 am – Aaron3 and Abe1 start the timers for the boxes (box A0 and B0).
9:00 am – Boxes A0 and B0 activate. **Aaron4 and Abe2 exit; Aaron4 exits early/late to appear new at time-travel.**
8:45 am – 2:45 pm – Aaron3 and Abe1 drive to and stay at a hotel in Russelfield. They research stocks at a library. **Aaron4 and Abe2 buy stocks in Abe's apartment.**
3:00 pm – **Aaron3 and Abe1 enter boxes A0 and B0. Aaron4 and Abe2 watch from the field.**
7:00 pm – **Aaron4 and Abe2 talk about what they would do if "above the law." The idea of punching Platts is spoken. Aaron's wife calls him a would-be hero, echoing the "hero" label already being applied to Aaron due to Robert's party, but Abe doesn't know yet. Aaron's wife mentions the "rats" in the attic, which is actually drugged Aaron0 (Original Aaron).**

Wednesday

8:45 am – Aaron4 and Abe2 start the timers for the boxes (box A0 and B0).
9:00 am – Boxes A0 and B0 activate. No one exits.
8:45 am – 2:45 pm – Aaron4 and Abe2 drive to and stay at a hotel in Russelfield. **They fill the truck with gas and discuss that punching Platts is impossible. They research stocks at a library and discuss telling Aaron's wife. Aaron's handwriting is terrible.**
3:00 pm – Aaron4 and Abe2 enter boxes A0 and B0. (This creates Timeline 6).

Figure 4: The extract of the document that lists the different timelines in *Primer* (2004)[1]

[1] Psykomakia (2005).

To get a fuller understanding of the relationship between the events that take place in a film, it often helps to use a graphical representation of the timelines, such as the timeline diagram in Figure 5, which was also created to explain how the events are related to each timeline in the plot of *Primer* (2004).

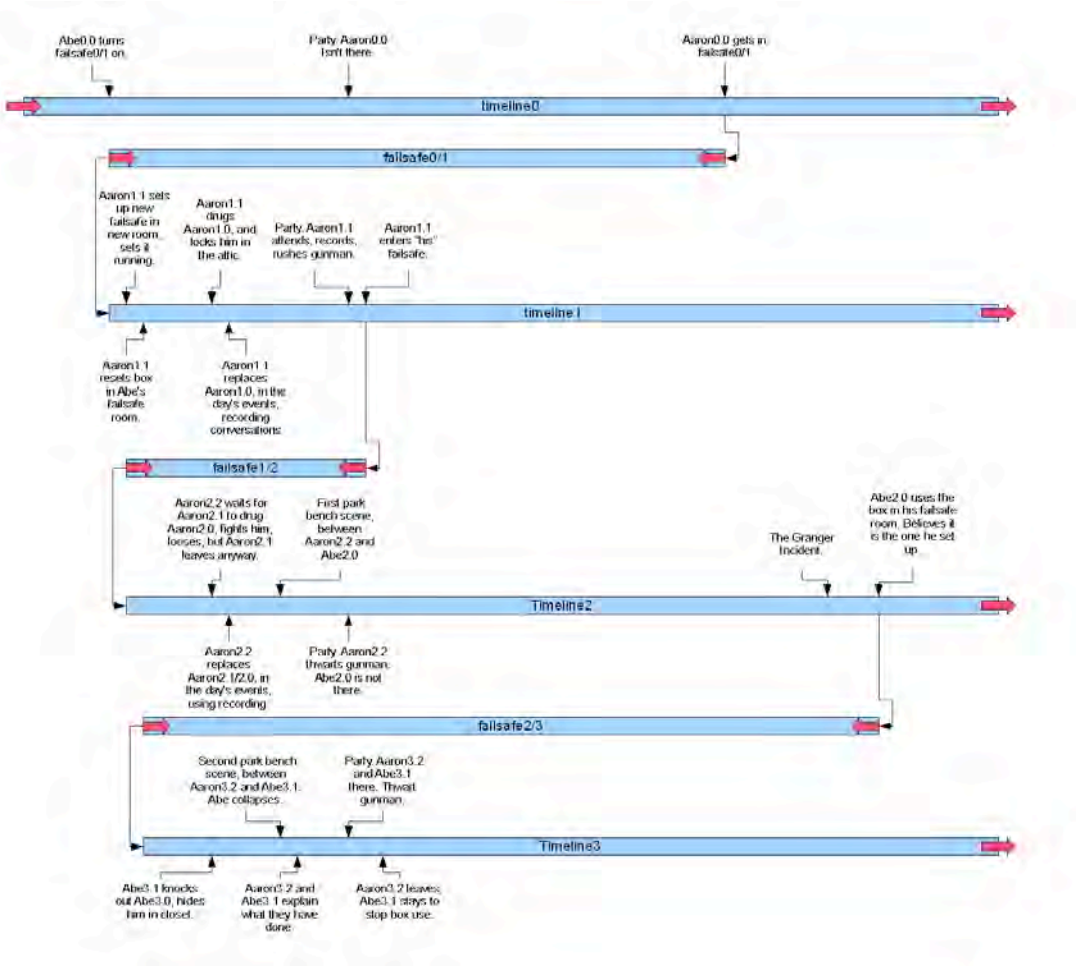

Figure 5: A timeline diagram for *Primer* (2004)[12]

As can be seen in Figure 5, every time one of the characters goes back in time, a new timeline is created in parallel to the original. A common feature of timeline diagrams is that arrows are used to show movement from one timeline to the other. This film is not a trivial example; it has one of the most complex time travel plots of all; however, after looking at the timeline diagram, it becomes easier to understand what is taking place and when. Note that in each of these timeline diagrams, time initially runs from left to right.

[1] Braedon (2009).ii

[2] The very complex plot of this film is explained in more detail in Appendix II on page 437.

In the film, *Prisoner of Azkaban* (2004), a simple time loop is created towards the end of the film, in which a series of causal events take place over the course of an evening. This can be easily explained using the timeline diagram shown in Figure 6. Note that a different colour is used to show when a new timeline is starting.

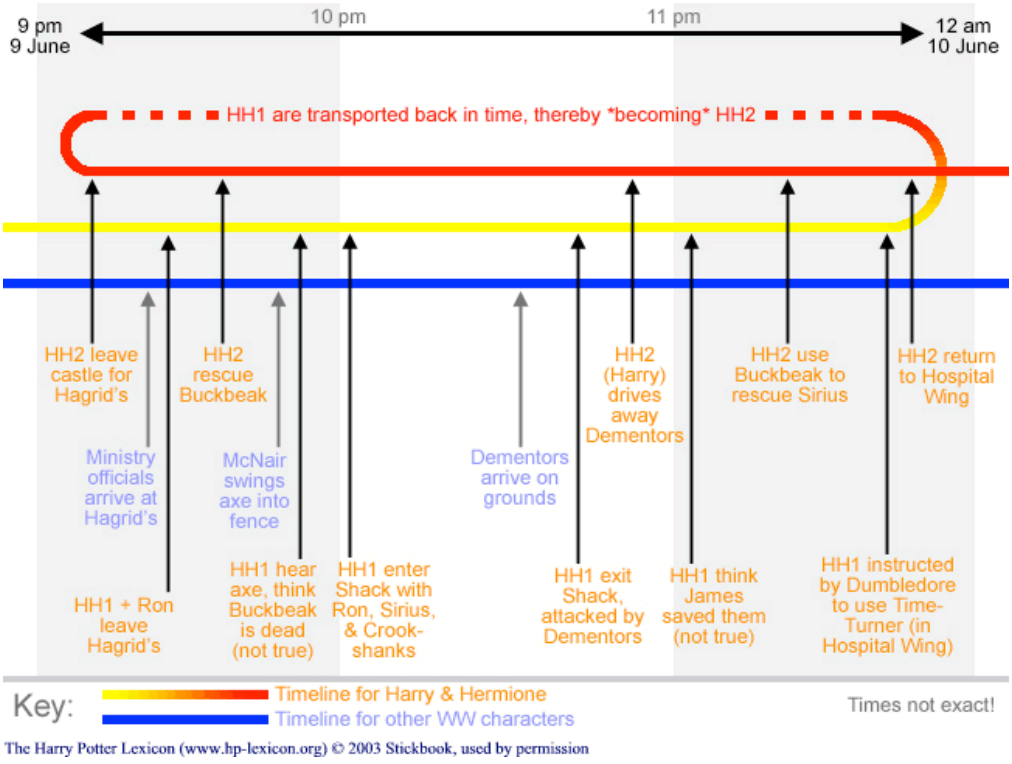

Figure 6: A timeline diagram for *Prisoner of Azkaban* (2004)[1]

In the film *Donnie Darko* (2001), there is a tangent universe in parallel to the original one. Figure 7 shows a timeline diagram that explains Donnie's travel to and from the tangent universe, and also to and from the past and the future.

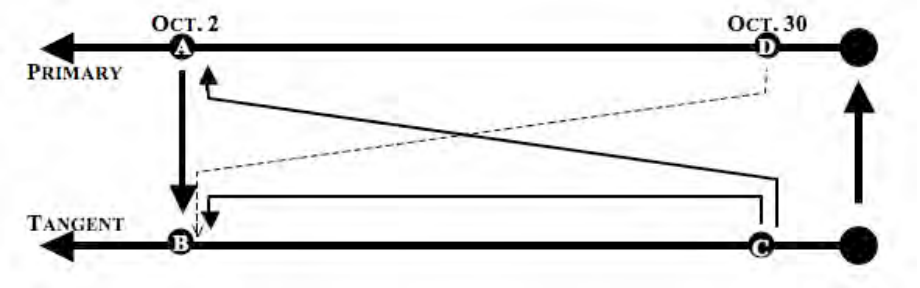

Figure 7: A timeline diagram used to explain the plot of *Donnie Darko* (2001)[2]

[1] Stickbook (2003). HH1 refers to the main characters, Harry and Hermione, and HH2 refers to them after they have travelled back in time, so they can view themselves taking actions earlier that day.

[2] Coburn (2011).

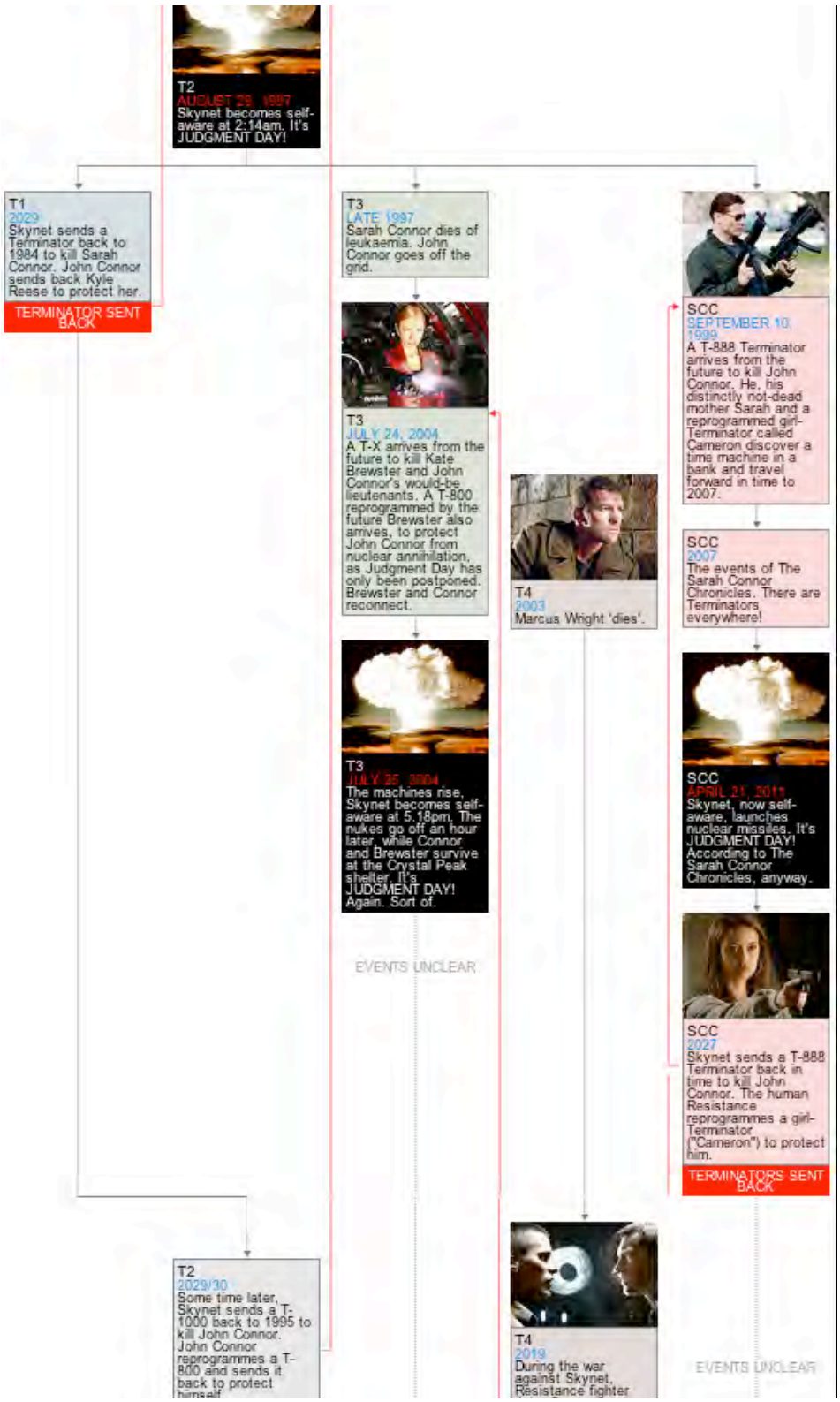

Figure 8: A portion of the complete timeline diagram for all four *Terminator* films and the spin-off television series, *Terminator: The Sarah Connor Chronicles* (2008 - 2009).[1]

[1] Bauer Consumer Media (n.d.).

A portion of the timeline diagram for the *Terminator* series is shown in Figure 8. It is different from the others in that the time axis runs down the page instead of across the page. As can be seen, after Judgement Day, there are three different futures, each represented by different vertical timelines.

The timeline diagram for the television series *Lost* (2004 – 2010) is shown in Figure 9. This is also different from the others because there is only one timeline, but it has four iterations. As can be seen, the characters can change some events, but always have trouble getting past the 2007 destruction of the island, so each time, they have to create a new iteration of the timeline.

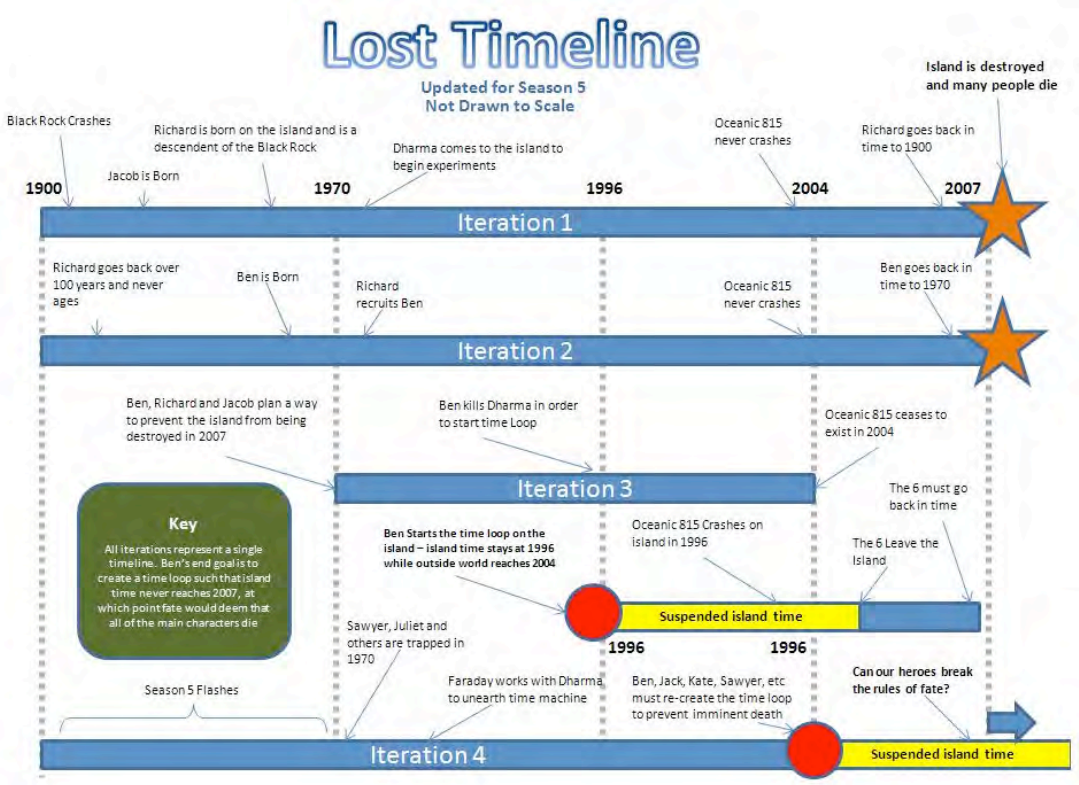

Figure 9: A timeline diagram for the television series *Lost* (2004 – 2010)[1]

A timeline diagram can be used to tie together a series of films as shown in Figure 10. A new branch of the timeline is created by each new version of the *Planet of the Apes* series of films, as represented by a different colour in the timeline. Note how the scale of time on the purple branch is not the same as the scale on the red one.

[1] Hunter (2007).

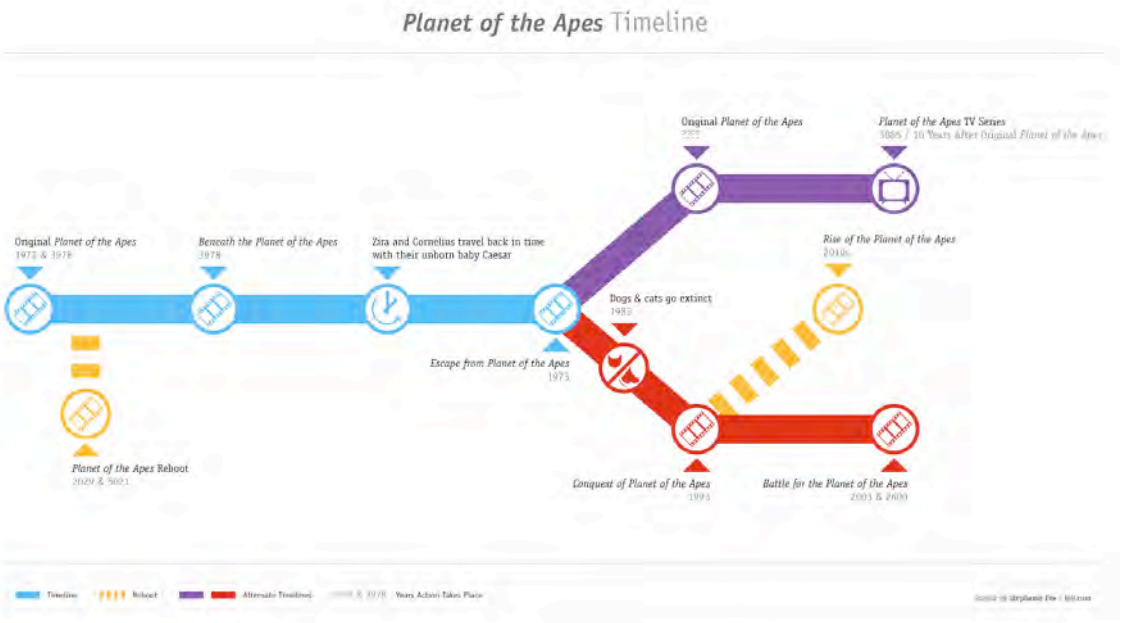

Figure 10: A timeline diagram for all of the *Planet of the Apes* films (2004)[1]

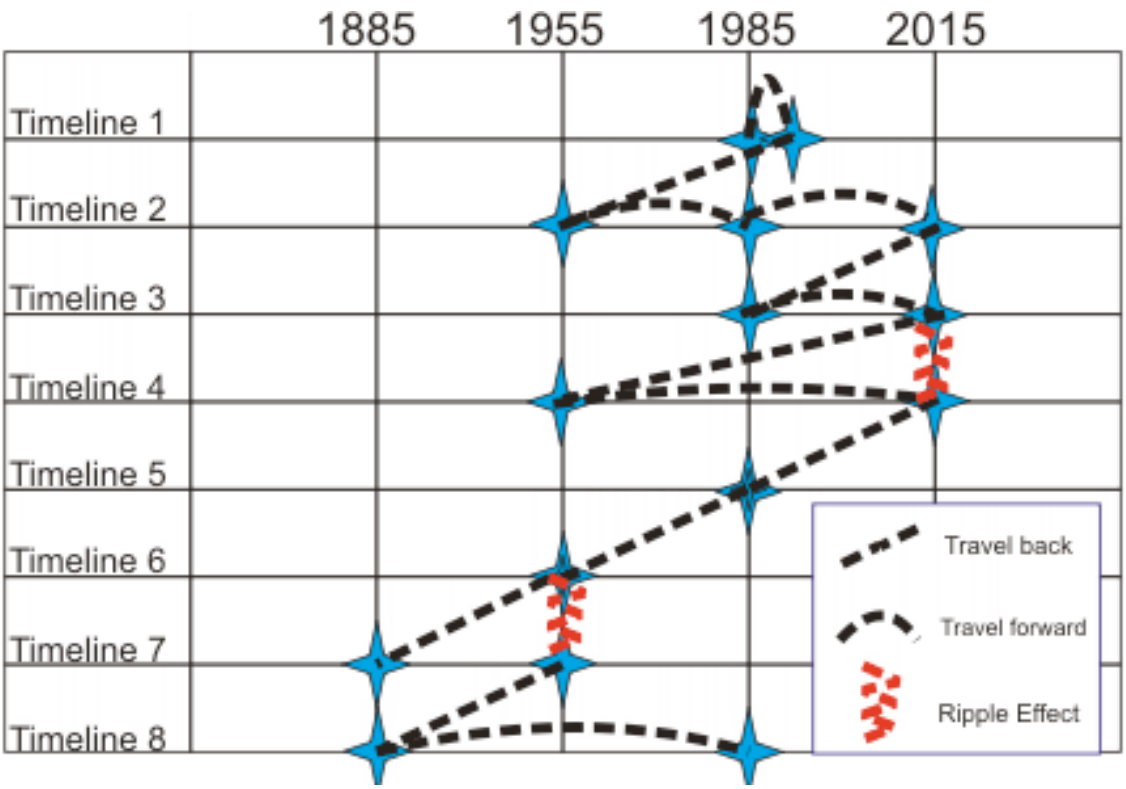

Figure 11: A timeline diagram for the *Back to the Future* trilogy[1]

[1] Newitz (2011).

The timeline diagram in Figure 11 for the *Back to the Future* trilogy uses straight dashed line for backward time travel and curved dashed lines for forward time travel. It also uses a 'ripple effect' to explain how events on one timeline are affecting those on another.

The timeline diagram in Figure 12 is similar to the one in Figure 11, but has different vertical lines for significant dates within a year, which is important because it shows how long characters travel along a timeline before they take off again. It also differentiates between the timelines of the different characters, which is important.

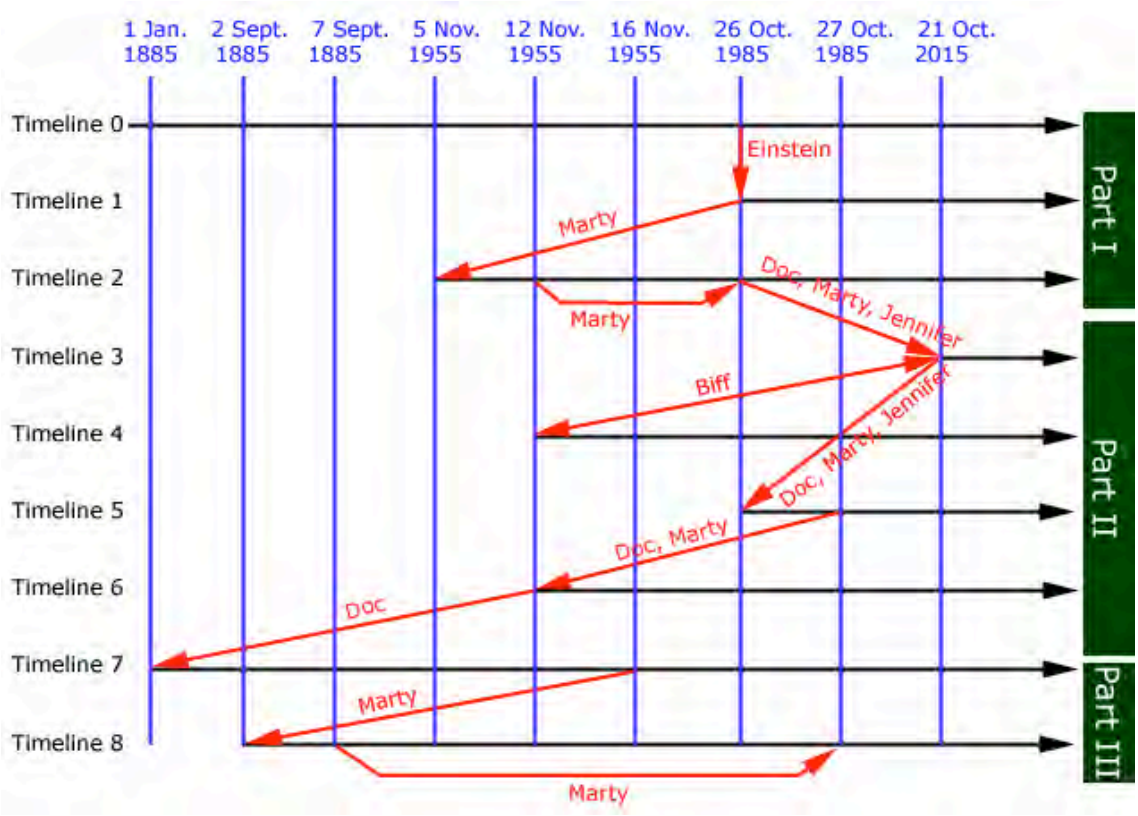

Figure 12: Another timeline diagram for the *Back to the Future* trilogy[2]

Rye (1997), another fan of time travel films, postulates on his blog, "There are four different possible sets of the 'law of chronophysics' for time travel plots in science fiction and fantasy." Each one of his four types of timeline shown in Figures 11-14 has two versions: a strict and a lax one.

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[1] Back to the Future timeline (2012).

[2] Tim (2006).

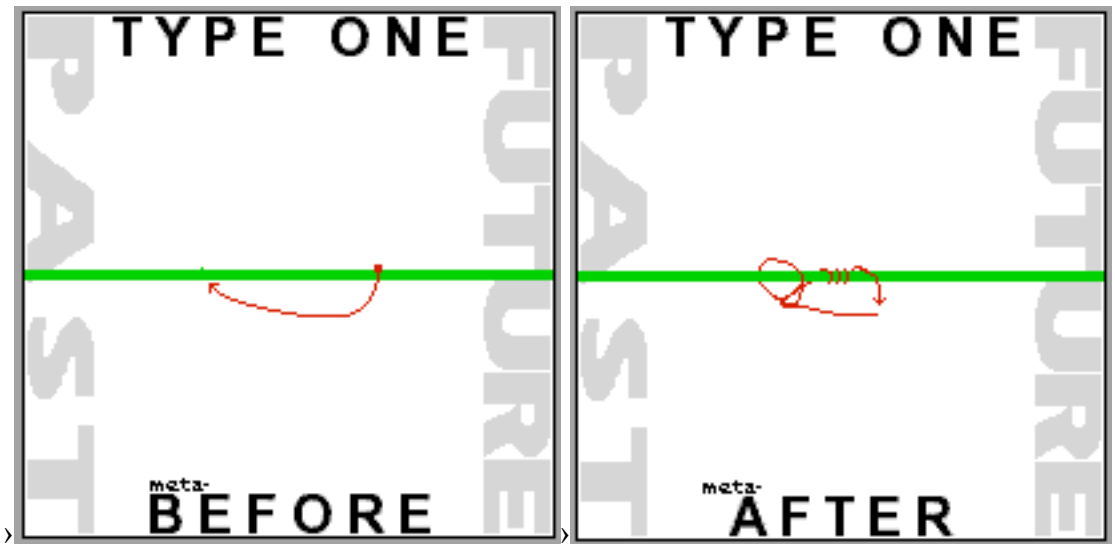


Figure 13: The deterministic (aka permanent) timeline

In the strict version of Rye's deterministic timeline, "history is utterly immutable. Attempts to 'ad lib' always turn out to have been scripted all along. [Whereas in the lax version] trivial changes are allowed."

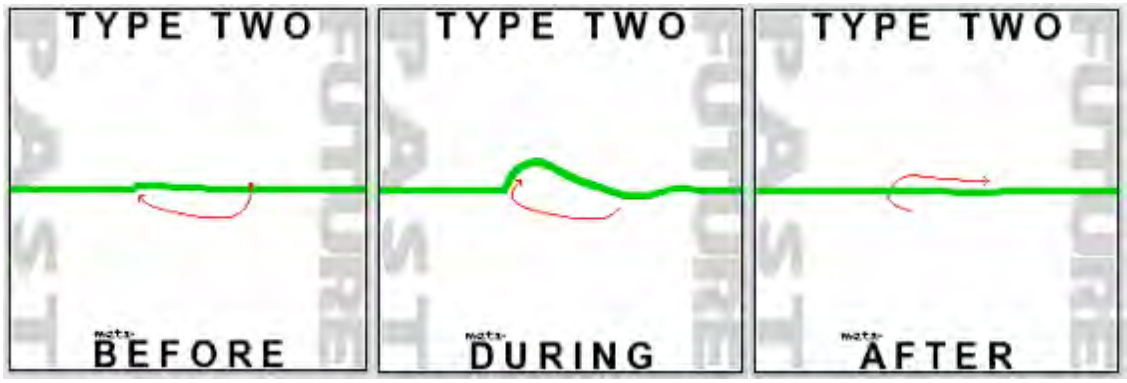


Figure 14: The elastic (aka resilient) timeline

In the strict version of the elastic timeline, "History has a preferred course/direction, and makes 'corrections'… for any interference. [Whereas in the lax version,] the timeline can be permanently diverted."

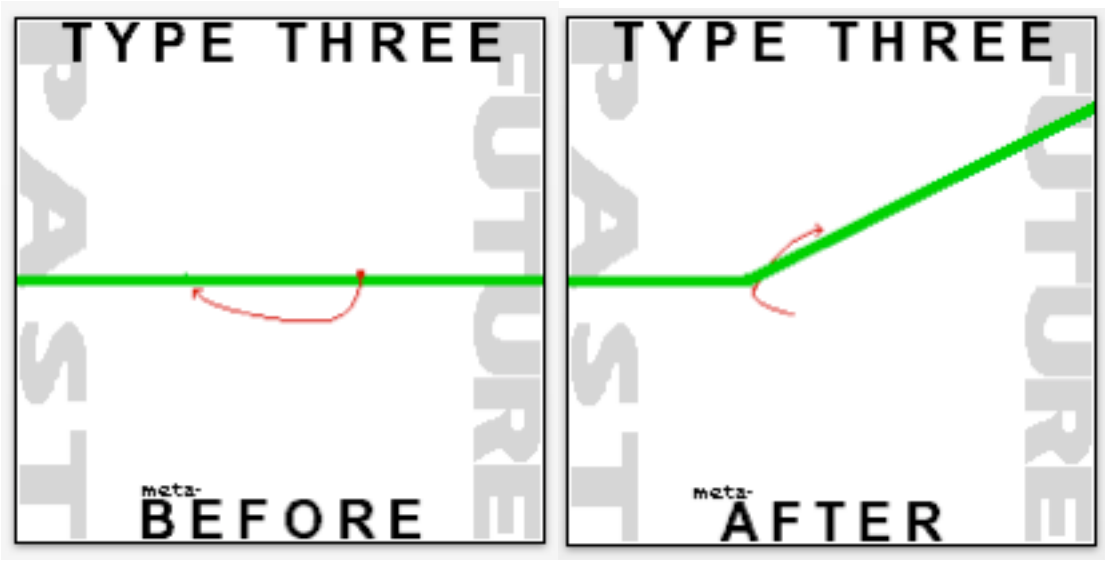


Figure 15: The overwriting (aka contingent) timeline

In the strict version overwriting timeline, "History is highly vulnerable. Any time travel 'erases' the original and replaces it with a freshly generated new version, [whereas in the lax version,] histories may be reluctant to diverge."

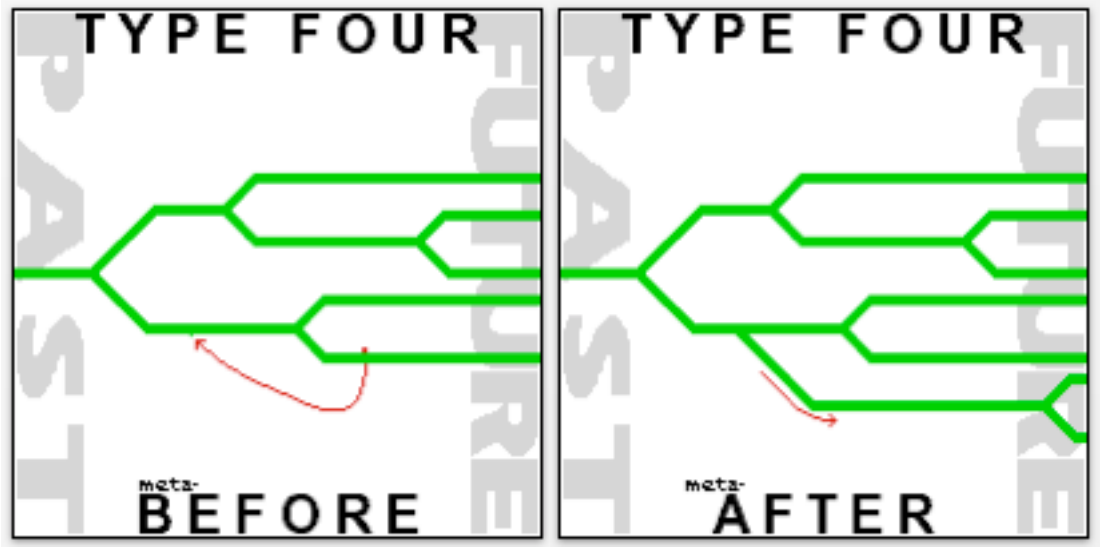


Figure 16: The quantum-forking (aka multi-divergent) timeline

In the strict version of the quantum-forking timeline, "the cosmos constantly bifurcates into all possible alternatives," whereas the lax version has a limited number of forkings only at "historic turning points."

One of the problems with this style of timeline is that it can take two or three diagrams to describe what could be drawn in one diagram.

McCandless, Busby, & Cho (2009) manage to fit in one diagram all of the trips ever made through time made by the characters in popular film and television into one timeline. As can be seen in Figure 17, the curving yellow x-axis that represents time had to be bent to fit all of the time travel journeys into the one image. Although an accurate diagram, this image probably has higher art value than practical use.

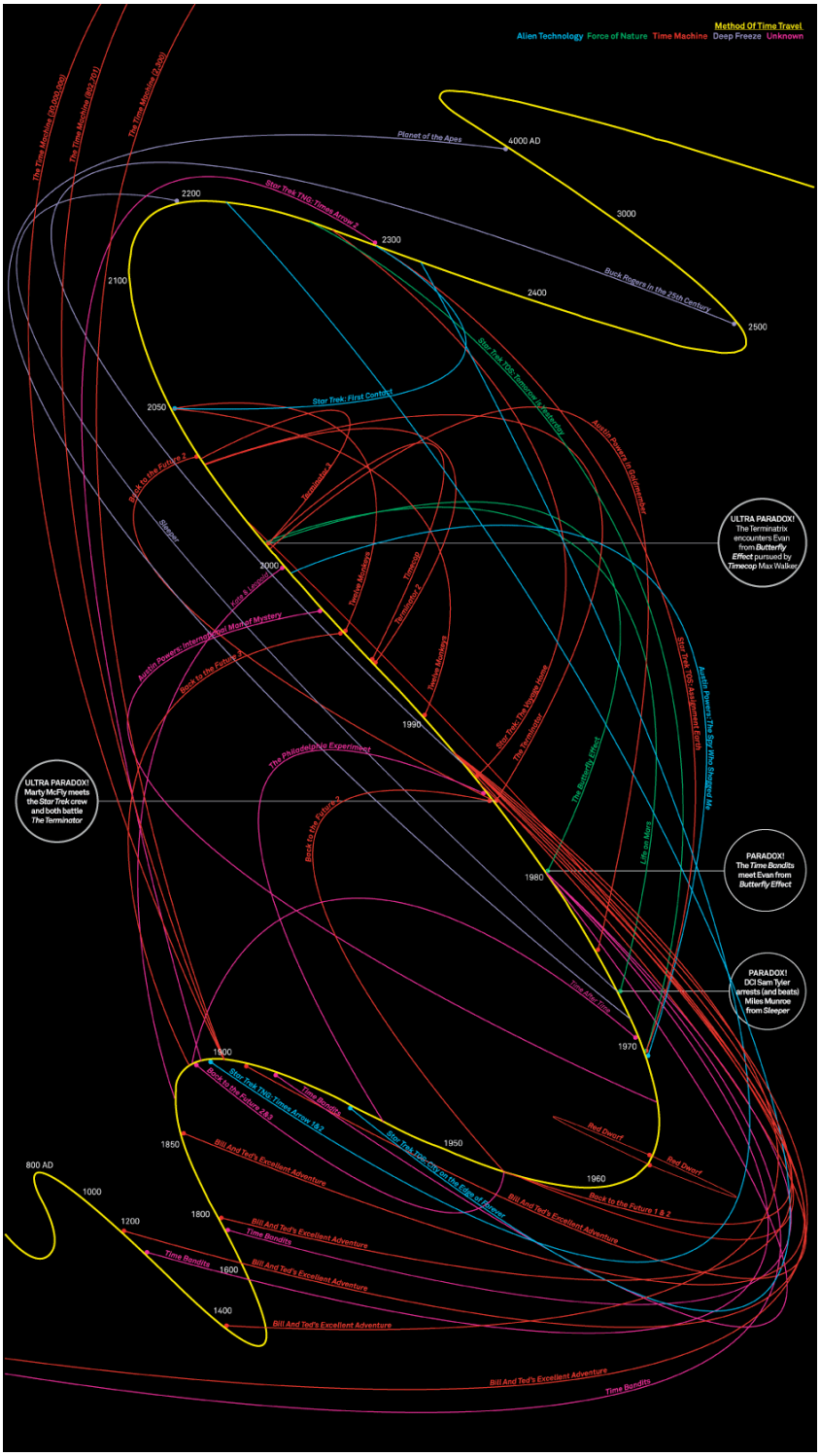


Figure 17: Timelines of time travel in popular film and television

As can be seen, various types of timeline diagrams have been used in order to explain the plots of certain time travel films.

Summary

In this chapter, I have shown that many authors have emphasised that public perceptions about science can be influenced by film, and they admit that the blurring of fact and fiction in film can be a problem if it leads to misconceptions about science. Many authors have also suggested that science in film should be represented as accurately as possible, and it was shown that most contemporary filmmakers agree as they now often choose to work with science consultants when making science-fiction films.

However, the problem is that although most experts agree that given the current state of physics, time travel of large objects (like people) is not physically possible, they do not agree on what will happen to someone who travels back in time if and when it does happen. Therefore, filmmakers have to speculate on what might happen when backwards time travel takes place in their films.

I have also shown that various attempts have been made to draw timeline diagrams that accurately describe what happens when a character travels through time in such films. However, these diagrams can be difficult to interpret, and they contain limited information: although they show time along one axis, the other axis is never defined, nor is the boundary between the past and the present. It has become clear that a consistent and comprehensive way in which time-related events are represented in time travel films is missing.

In this literature review, I was not able to find an accurate comparison of the models of time travel across a large sample of films, nor was I able to find a comprehensive set of models describing the possible consequences of time travel.

What I discovered was missing was a comprehensive set of models that could be utilised to compare the model of time travel being used in various films, and that could be used to determine the public's views about time travel and its consequences.

As a result of my literature search, I identified this unresolved issue, from which my main research question was formed:

‘Can the implicit models of time travel used in films be used to construct a comprehensive set of models about time travel and its consequences?’

There are three sub-questions:

1. What theories and ideas have researchers from science and philosophy produced about time travel?
2. What models of time travel can be constructed from films?
3. How do these models of time travel compare with the personal models being used by members of the movie-going public?

Chapter Three will explain the theories and ideas that researchers from science and philosophy have produced about time travel. It will summarise some of what they have written about the nature of time, backwards and forwards time travel, temporal paradoxes, chaos theory, and it will also offer some psychological perspectives on time.

CHAPTER THREE: THEORY

People like us who believe in physics, know that the distinction between past, present and future is only a stubborn, persistent illusion.

- Albert Einstein (1879 – 1955), theoretical physicist[1]

The main aim of this chapter is to identify the different theories and ideas about time that researchers in science and philosophy have produced. It is not designed to be a thorough account of everything ever written on the subject of time. Its purpose is to identify and describe the different theoretical models of time so that in Chapter Six they can be compared with those used in time travel films, and with the personal models of time used by the movie-going public. It is also intended to provide enough background information so that the discussions in the following chapters and in the film reviews can be read in an appropriate context.

This chapter covers the following topics:

1. The Nature of Time
2. Forwards Time Travel
3. Backwards Time Travel
4. The Paradoxes of Backwards Time Travel
5. Psychological Perspectives on Time Travel
6. Chaos Theory and Time Travel

The Nature of Time

The human experience of time

The moment that we are currently experiencing, we call 'the present'. The moments that were previously experienced are what we call 'the past' and the moments that we have yet to experience are what we call 'the future'. Is this just how we experience the passing of time? Or is this how we experience ourselves moving through an unchangeable (fixed) temporal dimension? If time is a fixed dimension, then why does it appear to flow? Physicists and philosophers are still trying to answer these questions

[1] As cited in McFarlane (2002).

and understand the nature of time, and as we will see, some are not even sure if time exists at all.

Two opposing views about time

Chen (2003) states the two best known opposing pictures of the nature of time are:

1) The conventional view, where time is split into three parts: the fixed past, which has gone; the present, which we are experiencing now; and the open future, which has yet to arrive. Therefore, time is flowing past us.

2) The 'block universe' view, where all events from all time exist on a four-dimensional spacetime 'fabric'. As it is possible to move through this fabric at different speeds, time will not be the same for everyone, so a universal present moment cannot exist.

She also states that the debate between the conventional view and the block universe view combines two debates in the philosophy of time: (i) the A-theory versus the B-theory of time and (ii) presentism versus eternalism.

The A and B theories of time

This debate in the philosophy of time was started when J. M. E. McTaggart (1908) proposed that all events could be ordered in time in one of the following two ways:

The 'A-series of time' describes the temporal position of an event in relation to the present moment (in absolute tensed terms such as: 'yesterday', 'now', or 'next year'). So an event would be in the future before it enters the present moment and then becomes part of the past. The temporal description depends on the temporal perspective of the observer; therefore, a tense needs to be specified. For example, 'This morning we were married, and tomorrow we will be on our honeymoon.' The temporal position of both events is stated relative to the present moment.

The 'B-series of time' describes the temporal position of an event only relative to another event (in untensed temporal relations such as: 'before', 'at the same time as' or 'after'). One event would precede another, follow it, or take place at the same time. All events have fixed temporal positions, and no universal present moment can exist. This series is non-tensional: a tense does not need to be specified. For example, 'The day

after we were married, we went on our honeymoon.' The temporal position of both events is stated relative to each other without reference to the present moment.

Note that the order of events in both series is identical, as is the time difference between them. What is different is that in the first example, the phrase is spoken as if the B-series of events slides along a fixed A-series. In the second, it is spoken as if the A-series slides along a fixed B-series. McTaggart argued that the A-series was not logically coherent because each point in time must possess all of the different A properties (past, present and future). He then went on to argue that the B-series was incomplete without the A-series because it did not involve change in itself. Therefore, he concluded that time must be unreal.

The debate has continued ever since and many philosophers and most physicists now agree that the A-series can be discarded, mainly as it is contrary to proven theories of modern science, like special relativity. Most commentators dispute McTaggart's conclusion that time is unreal – on the grounds that the B-series is all that is needed for time. This belief is known as 'The B Theory of Time' and its proponents are called 'B-theorists'. They argue that a date only has the property of being past because we are speaking at a date that is later than the first. Markosian (2008) states that, "There is no sense in which it is true to say that time really passes, and any appearance to the contrary is merely a result of the way we humans happen to perceive the world." The subjective illusion of the passage of time is maintained by the fact that we can remember events from the past, but not events from the future and also by the fact that events appear irreversible due to the 'arrow of time'.

Presentism

One definition of presentism is, "the view that only present objects exist" (Markosian, 2008). Around AD 400 Saint Augustine of Hippo argued that the present was the border between the past and the future. It could have no duration in time because if it did, then it would be possible to split it into separate parts, which could then be sorted into past and future parts. His conclusion was that "past and future exist only in the mind" (Le Poidevin, 2009), which means that they cannot be considered to be real.

The Greek philosopher Aristotle agreed and added that the world must be made up of a three-dimensional space of width, breadth and depth. Petkov (2006, p. 208) states, "The

two defining features of presentism – the world exists only at the present moment and the world is three-dimensional – are intrinsically linked: if the world is three-dimensional, it exists only at one moment of time and vice versa."

Presentism has many varieties, one of which is the Buddhist philosophy of time, as described by Yandell (1999, p. 5):

> A core Buddhist doctrine is that everything is impermanent. Hence persons are impermanent. At a time, a person is one or more purely momentary states. Over time, a person is a series of such bundles…. Strictly speaking, for the Buddhist the world's history is a matter of one set of states being replaced by another set, which in turn is replaced by another.

The 'Nowhere Argument' in philosophy suggests that if the past and present do not exist, there is nowhere for the time traveller to go, which implies that time travel is impossible in the presentist model. However, Keller & Nelson (2001) argue that although the past and future may not exist, they still have definite truths, which could be used to explain a time traveller appearing in the present.

The block universe theory of time

"Physicists prefer to think of time as laid out in its entirety—a timescape, analogous to the landscape—with all past and future events located there together. It is a notion sometimes referred to as block time" (Davies, 2002b, p. 40). In his 'Special Theory of Relativity', Albert Einstein (1905) proposed that time separation is variable depending on the frame of reference in which it is measured, and that the speed of light in a vacuum is a constant. He disagreed with Sir Isaac Newton, who thought that there was a universal time independent of space. Special relativity shows that time separation is relative. Minkowski then postulated the existence of a four-dimensional 'spacetime continuum'. This is made up of the three dimensions of space along with the fourth dimension, which is time. The consequence of this spacetime continuum is that all the past, present, and future exist eternally (Barbour, 1999, p. 143). Therefore, maybe time is not passing us, but we are experiencing ourselves passing through the dimension of time? The block universe is a theory of space and time that "affords equal (ontological) status to all points in spacetime, thus regarding temporality as an illusory human construct with no reference to reality as understood by modern physics" (Darling, 2010).

Eternalism

"Eternalism … says that objects from both the past and the future exist just as much as present objects" (Markosian, 2008). It is the belief that events in the past and future exist eternally. An event that has been experienced is no longer in the present, but it would not have disappeared because it is real and will exist forever in spacetime. Therefore, eternalism is diametrically opposed to presentism. Past and future are regarded as directions, which depend on your frame of reference. An eternalist would agree that a clock does not measure the passing of time; it measures the duration between events that are spaced out along a spacetime continuum. All points in spacetime are equally real and equally fixed, so the future can no more be changed than the past. All events exist on a timescape, just as all places exist on a landscape.

Although Saint Augustine of Hippo believed in presentism, he concluded that time must only exist within the created universe because an omnipotent God would have to live outside of time if he was to be present in all eternity. It is interesting to note that if this were true, time would appear to God like the block universe just described.

The growing (or evolving) block universe theory of time

"A gradualist believes in a growing block: he agrees with the eternalist about the past and the present but not about the future" (Stoneham, 2009, p. 201). This is an alternative view to both eternalism (the idea presented in the block universe that time is a fixed dimension where all of time is real), and to presentism, (the idea that time flows through the present moment, which is the only reality). The growing block is a compromise between presentism and eternalism because as time passes, the block continually grows and more of the world comes into being. This is closer to representing how most humans experience time in their life, as the past and present are known, whereas the future is not. This theory requires a universal present moment, which goes against Einstein's special theory of relativity. The problem that many have with the block universe is that our knowledge of the past is so different from the present and the future. However, this might just be due to the fact that our brains can store past memories and not future ones, rather than due to the nature of time itself.

Free will and determinism

O'Connor (2008) defines free will as "a philosophical term of art for a particular sort of capacity of rational agents to choose a course of action from among various alternatives." There is a difference between free will and free action. If we choose an outcome, it does not mean it will come to fruition because there could be external constraints at play that prevent the desire from becoming a reality, i.e. the possible actions that arise from the exercise of free will are limited. With presentism, there are various alternatives to choose from, but not unlimited ones. With eternalism, the external constraints are so strong that all free will is suppressed to the point that no free action can take place and only 'causal determinism' is left. This is when the future is entirely determined by past events, and the laws of nature and all future events are immutably fixed in the fabric of spacetime. The definition of determinism as given by Hoefer (2010) is that "if and only if, given a specified way things are at a time *t*, the way things go thereafter is fixed as a matter of natural law." Adler & Gielen (2001, p. 159) discuss a scientific notion of determinism, with its emphasis on causality and its denial of noncausal events that became very popular with rationalist philosophers, and they note that:

> It was not until the emergence of quantum mechanics in the early twentieth century that determinism in science, if not in human affairs, once again came to be seriously questioned. In keeping with his own views on the subject, Popper (1988) avoids the terms 'determinism' and free will' altogether. Instead, he proposes the term 'indeterminism', which he argues is neither the opposite of determinism nor the same as free will.

Adler & Gielen (2001, p. 160) also point out that the notion of determinism plays an extremely crucial role in the thinking of people from India:

> The law of karma, which involves determinism and fatalism, has shaped the Indian view of life over centuries…. A belief in the law of karma does not necessarily negate the notion of free will. As Christoph von Fürer-Jaimendorf (1974) has pointed out, in an important sense karma is based on the assumption of free will.

Sarvepalli Radhakrishnan, the second president of India and a highly regarded scholar of comparative religion and philosophy, argues that "the theory of Karma, properly understood, is not a theory of predestination, but rather a theory that is completely consistent with the causal laws of the universe" (Tiwari, 2009).

The Bhagavad-Gita is an important Hindu scripture whose teachings have helped to shape Indian philosophy and culture for many centuries (Nikhilananda, 1944, p. 1). One of its teachings is what we call today the perennial philosophy, and part of that states that “an infinite unchanging reality exists hidden behind the illusion of ceaseless change [meaning] that the passing moments of time are illusionary” (Wolf, 2004, p. 14).

The scripture contains a story about the warrior Arjuna, who is conflicted about having to go into battle against his loved ones. He realises that his charioteer is actually Krishna, an incarnation of the Supreme Being. He gives Arjuna divine eyes so that he may temporarily see his unlimited universal Self: hundreds of thousands of varied divine and multi-coloured forms all in one place with no end, no middle and no beginning. Also, “Arjuna could see in the universal form of the Lord, the unlimited expansions of the universe situated in one place although divided into many, many thousands" (Krishna, 2005). Wolf (2004) elaborates, “Krishna tells Arjuna that He is Time and that from His point of view the battle is already over and the outcomes determined. This would be similar to a model of time with an infinite number of parallel worlds all existing alongside one another, but each one with a slightly different destiny. Figure 18 shows how Krishna might have appeared to Arjuna with his many forms of being revealed.

Figure 18: An artist’s impression of the many forms of Krishna being revealed to Arjuna[1]

[1] Retrieved 2 May, 2010, from http://www.hinduyuva.org/tattva-blog/wp-content/uploads/2007/11/ekam-sat.gif

Cultural perspectives on time

The modern western view of time is a "linear time concept, represented as a horizontal arrow, [which] reflects an individual's life characterized by a single stream of time from birth to death" (Joel Hunter, 2004). The Holy Bible states that the world began when God created the world out of nothing, and that it will end with the Last Judgement, again a linear concept with a start point and an end. "Each moment occupies its own distinct position in a temporal series that tells a story of linked events moving in one direction…. Also implicit in this picture is the idea of progress in direction, an idea impossible of conception if patterns merely repeat themselves" (Jablonsky, 1997, p. 5).

Goldfajn (Yamada, 2006) argues, "The idea of linear time has not always been the prevailing view. Many ancient cultures, based on the regular cycles of the tides, seasons, and the recurrent movements of the heavenly bodies, regarded time as essentially cyclic in character." Jablonsky (1997, p. 6) explains how time's cycle in its pure metaphorical form is the opposite of linear time:

> Events in this picture have no meaning as distinct episodes with causal effects upon contingent history. Fundamental states remain immanent in time, forever present, never changing. And what appear to be motions are actually part of repeating cycles. Time, in short, has no direction. The differences of the past are destined to be realities of the future.

In ancient Greece, people generally conceived of time as a circle. "The concept of cyclical time, though, reaches far beyond ancient Greece. It is quite common in the Pre-Columbian civilizations of South and Central America, where it appears in the old Indian cultures of the Maya and Aztec people" (Goldfajn, 1998, p. 34). The Maya civilisation of Central America believed, for example, that history repeats itself every 260 years, which included a cycle of recurring catastrophes (Cullhed, 2001).

Cultures and religions that have survived western influence resist the concept of linear time, such as in India. Adler & Gielen (2001, p. 158) state, "Time, in Indian philosophy, is conceptualised in circular terms, which means that time has no beginning, no middle and no end, or, if there is a beginning, it remains unknown." They also note that in Hindi the same word – kal – stands for both yesterday and tomorrow, and "at a day-to-day observational level, one does not notice among Indians the same sense of urgency that appears to have become the hallmark of Western society."

Wolf (2001, p. 158) writes that time for the Australian Aborigines appears as a rhythm or cycle:

> I think of it as a sacred hoop that, for the Western mind, can be pictured as rolling along and touching [the] line-time at every instant. Hence the direction of time becomes immaterial' it simply doesn't matter what is past, present and future. The important thing is the presence of the hoop touching life, as indicated by the line of time it touches at every moment.

Goldfajn (2004, p. 71) suggests, "It has often been argued that it was the Judaeo-Christian tradition which established time's arrow or linear time as the primary Western metaphor of time." Augustine of Hippo, a Christian saint who lived in the fifth century, "argued strongly in favour of this linear concept of time, condemning ancient Greek cyclic time as a superstition" (1998, p. 35).

In our western world, we are taught to use the words 'before' or 'after' to describe events that happen in relation to each other, or to use the past and future tenses to describe events in relation to a universal now. "Our grammar books … generally assume that time can be represented as straight line; the past being represented conventionally to the left, the future to the right and the present acting as the central anchor point" (Cullhed, 2001). The way in which we speak is based on a linear representation of time with the identification of the present moment as the divider between the past and the present. "The standard linear representation of time in linguistics has been occasionally criticized as inappropriate, and even misleading. The most famous objection … has come from linguists who claim that certain cultures have absolutely no concept of time" (Goldfajn, 1998, p. 35). For example, Whorf, an expert on the topic of linguistic relativity, wrote that "The Hopi language is seen to contain no words, grammatical forms, constructions or expression that refer directly to what we call 'time', or to past, present or future, to enduring or lasting" (Goldfajn, 1998, p. 37).

Members of the western public are aware of time because they learn to use it from an early age, but only see it as linear. Braud (1956, p. 57) writes, "In the thrall of what Huston Smith has called the 'Modern Western Mindset', we rarely, if ever, pause to question the prevailing view of time as linear and unidirectional."

Also, the following studies agree that culture can influence beliefs about both physical time and personal time. The first study compares students in America, Japan and Malawi, and it concludes, "Belief structures and beliefs concerning physical time and

personal time were somewhat different across the three groups, suggesting cultural influences" (Block, Buggie, & Matsui, 1996, p. 5). The second study compares beliefs about time among black Americans, black Africans, and white Americans and concludes, "Culture may differentially influence beliefs about physical time and personal time" (Hill, Block, & Buggie, 2000, p. 443).

Iowa State University (n.d.) agrees that there are cultural variations in how people understand and use time:

> Researchers have found that individuals are divided in two groups in the ways they approach time. Monochronic individuals … view time as if it were linear, that is, one event happening at a time. Examples of monochronic cultures include the U.S., Israel, Germany, and Switzerland. Polychronic individuals … usually see time in a more holistic manner; in other words, many events may happen at once. Latin America, the Middle East, and Africa are places where the polychronic orientation prevails.

Following on from whether time is linear or circular is the debate about whether or not time is unidirectional.

The arrow of time

The Second Law of Thermodynamics states that at any given temperature, the entropy of an isolated system increases with time until it reaches equilibrium, where "[e]ntropy is the quantitative measure of disorder in a system" (Jones, 2010). For example, if a drop of red water is placed into a body of clear water, it will spontaneously disperse. This is an irreversible process because it is extremely unlikely that the red water will ever spontaneously reform into a drop, so what gives time its direction? Price (1996, p. 16) argues that "we need to distinguish the issue *of* time from that of the asymmetry of things *in* time." He states that it is important to draw a distinction between how things *seem* and how they actually are. He therefore suggests that the view from 'nowhen' – an atemporal viewpoint taken from outside of time – would reveal the true symmetrical nature of time as predicted by the block universe. The equations of physics show that any physical process that is allowed by the laws of physics should be able to be reversed.[1] The fact that the laws of physics are symmetric, but that we observe irreversibility is known as Loschmidt's paradox.

[1] The only known exception being a particle called the neutral kaon (Price 1996, p. 16).

So, there only *appears* to be an arrow of time to observers because they exist in the dimension of time. If they were to view the world from outside of time, they would be able to watch broken objects reforming just as easily as watching them break. "But there is no limitation on free will, according to Price. We are free to make any decisions we please ... The past already knows what those decisions will be, but that does not affect our freedom in making them" (Gribbin, n.d.).

If the arrow of time is related to entropy, what happens when our ever-expanding universe reaches maximum entropy? Boltzmann (as cited in Roeckelein, 2000, p. 138) suggests:

> At some undefined date in the future, nothing will be hotter or colder than anything else; the slowest radioactive elements will have decayed into stability. The stars will have burned out … and humans will be long extinct. Thus in such a burned out universe – as reckoned by the physical science approach – there will be no change by which time can be observed or measured, and in some abstract or metaphysical sense time may yet exist but, scientifically speaking it will have ended.

A universe without time

Yourgrau (2005a, p. 6) notes that after Einstein transformed time into space, Kurt Gödel found a way of making time disappear altogether using new and unsuspecting cosmological solutions to the field equations of general relativity. He goes on to say:

> In [one of] the possible worlds governed by these new cosmological solutions, the so-called rotating or Gödel universe, it turned out that the space-time structure is so greatly warped or curved by the distribution of matter that there exist future-directed paths by which a spaceship, if it travels fast enough … can penetrate into any region of the past, present or future.

Richmond (2003, p. 307) points out, "In Gödel's rotating universes, time appears to be deprived of a unique direction and no division of the universe into global time-slices is possible." Although we do not live in a rotating universe, Gödel was quick to point out that if the laws of relativity allow us to revisit the past, then it never really passed, and that a time that fails to pass is no time at all.

In the field of theoretical physics, quantum mechanics and general relativity are only accurate within their own domains, so physicists are working on new theories that attempt to unify the two into a universal 'quantum theory of gravity'. General relativity treats space and time as a four-dimensional fabric, and is very accurate at describing large-scale phenomena. On the other hand, quantum mechanics is very accurate at

describing microscopic phenomena, but it requires a clock outside of itself to keep time. Therefore, it cannot be applied to the whole universe, which could suggest that time is not fundamental. Barbour (2009) in an overview of his book *The End of Time* argues that time cannot exist in a universal quantum theory of gravity:

> If we could stand outside the universe and 'see it as it is', [time] would appear to be static. I arrive at this radical conclusion by considering the most basic structure of Einstein's general theory of relativity and quantum mechanics … all serious workers in the field are convinced that the two theories must eventually be subsumed in a single over-arching theory. This will be the quantum theory of the universe (also called quantum gravity). The finding of this theory presents many great difficulties, of which the 'problem of time' is perhaps the most severe. It seems that a choice has to be made between two irreconcilable notions of time. I argue that the only satisfactory solution is to abolish time altogether.

Hellmann, Mondragon, Perez, & Rovelli (2007) propose a new theory of quantum mechanics without time, which defines quantum probability in the context of "timeless" general-relativistic quantum mechanics. This is not the only such theory, but many physicists agree that time is the key obstacle to finding a unified theory of the universe. Richmond (2003, p. 308) adds, "it may be that future discoveries in physics, including the long-sought theory of quantum gravity, may yet shed new light on the issues [surrounding time travel]."

As shown, many philosophers and physicists cannot agree what time is or whether it even exists; therefore, the subject of time travel can be even more contentious. Richmond (2003, p. 297) says, "If a diversity of approaches and a continuing debate about fundamentals are signs of health then the philosophy of time travel is positively thriving."

Forwards Time Travel

One standard definition of time travel is that of philosopher David Lewis, who states, "An object time travels if the difference between its departure and arrival times in the surrounding world does not equal the duration of the journey undergone by the object" (Joel Hunter, 2004). There are several speculative theories about how it might be possible to send an object or even just information backwards through time, and often these bring temporal paradoxes with them. However, forwards time travel is a little less complicated, so I will review some of the different methods that are used and discuss how the technology is progressing.

Time dilation and relativity

The four dimensions of spacetime all relate to a constant. So for example, the faster a rocket moves through the three dimensions of space, the 'slower' it moves through the dimension of time. This means that a rocket's on-board clock, as observed from Earth, is ticking more slowly than a clock back on Earth – a concept known as 'time dilation'. If an astronaut in the rocket had an identical twin brother back on Earth, they would have been the same age when they parted. Let us say that he travelled so fast in space that during his year of travel, ten years had passed on Earth. This means that on his return, he would be nine years younger than his twin. This is not a paradox, merely an application of Einstein's Special Theory of Relativity. In the extreme case, the astronaut could return to the Earth's distant future. So forwards time travel is a reality: how far forwards a person can go in time depends on how fast their technology will allow them to travel through the three dimensions of space. Time dilation really only becomes significant when the velocities approach the speed of light. For example, "When we accelerate tiny particles to 99.99 per cent of the speed of light in the Large Hadron Collider at CERN,[1] the time they experience passes at one seven-thousandth of the rate it does for us" (Cox as cited in news.com.au, 2010).

Einstein's General Theory of Relativity predicts 'gravitational time dilation'. If two synchronised clocks are separated, the clock that is in the stronger gravitational field will "tick" more slowly; therefore, an astronaut close to a black hole will age more slowly than one farther away. An example of time dilation that brings both relativity theories together is a global positioning system (GPS) satellite. A GPS receiver on Earth can calculate its location and bearing by comparing the time on the atomic clocks of a number of GPS satellites that orbit our planet by triangulating on the known positions of each satellite. Pogge (2006) states that because these satellites travel with an orbital speed of about 14,000 km/hour, their on-board atomic clock, as observed from the Earth, should fall behind our clocks at the Earth's surface by about seven microseconds per day due to time dilation. However, due to gravitational time dilation, their clocks should gain on our clocks' time at the surface by about 45 microseconds per day. So the net result of these two effects is a gain on the atomic clock of a GPS satellite of 38 microseconds per day. In order to locate a position within five to ten metres on Earth, our instruments need to read the atomic clocks of the satellites with an accuracy of

[1] CERN is the European Organization for Nuclear Research, based in Geneva, Switzerland.

between 20-30 nanoseconds. This would not be possible without making a correction to take into account both types of time dilation. Although it is only a fraction of a second, this real life example of time travel is used every day in satellite engineering.

If two events, X and Y, are separated in space, it is not possible to say in absolute terms whether they occur simultaneously or not. One observer may see X happening first, while another, who is moving with respect to the first observer, may view them occurring simultaneously. Defining a single event as the present moment could cause problems because this event may be observed before or after a spatially separated event by different observers depending on their frame of reference. Therefore, the spatially separated event could exist in the past for one observer while in the future for another. This is known as the 'relativity of simultaneity'.

Suspended animation and cryogenic freezing

'Suspended animation' uses cold temperatures or chemicals to drastically slow down the respiratory systems of animals or humans, which causes them to age more slowly. Currently, this can only be achieved for a few hours in the laboratory, but it can happen for longer periods by accident: in 2006, a Japanese man was reported to have survived for 24 days in cold weather and without food and water by falling into a hypothermic state similar to hibernation. When found, his body temperature had dropped to 22° C (71° F), his organs had shut down, and he had almost no pulse (BBC News, 2006).

'Cryonic freezing' otherwise known as 'cryonics' is different in the sense that the whole body is completely frozen just after the heart stops beating – in the hope that it can be thawed at a later date and brought back to life.[1]

> Cryonics advocates [state] that if the pattern of our neural interconnections (which encodes our personality, memories, emotions, everything) are frozen at extremely low temperatures, then they will not degrade, and the person should not be defined as "dead" per se. Given sufficiently advanced technology, the patient could be warmed up to room temperature and their metabolism rebooted.
>
> (Anissimov, 2010)

Scientists in this emerging medical field are currently able to perform cryopreservation using liquid nitrogen; however, the technology to bring them back to life does not exist yet – although this may be possible in the future.

[1] This should not be confused with 'cryogenics', which is the scientific study or production of extremely low temperatures (below –150 °C, –238 °F or 123 K) states Anissimov (2010).

An application of both suspended animation and cryonic freezing would be long distance space travel, where for example, an astronaut's body could be revived after a journey lasting longer than his normal life. Another application might be to save the lives of seriously ill people by temporarily putting them in such a state until a future time when a cure had been found and a treatment could be given. A big difference between the two methods is that a body in suspended animation is still alive, whereas a cryogenically frozen body is considered to be legally dead - until such time as it is revived. If a subject were revived with a working body and full memory, then this would constitute a form of time travel.

Although cryogenic technology has not yet been fully developed, forward time travel is definitely possible using time dilation. Only our engineering technology limits how far forward in time we can go. However, travelling the opposite way through time is not so straightforward. Tandy (2007, p. 80) states that "most experts agree that biological technology related to suspended-animation, and space technology related to superfast-rocketry, will advance to give us the technical ability to travel to the far future." He goes on to say "many experts believe that one or both of these techniques may advance rapidly enough to allow some persons alive today (and still alive when the first time machines have been perfected) to travel to the far future.

Backwards time travel

For centuries, philosophers have been pondering whether backwards time travel might one day be possible, and now many physicists are busy creating speculative theories, even though the technology required for them is still a long way off. Greene (as cited in Boyle, 2006) states that "Many physicists have a gut feeling that time travel to the past is not possible, but many of us including me are impressed that nobody's been able to prove that." Following are some of the various technologies that might be used to one day create backwards time travel.

Faster than light travel

As discussed, the closer an object's velocity gets to the speed of light, the further it will be travelling forward in time relative to us. If an object could travel at the speed of light, time for it would stop altogether from the perspective of neutral ovserver; and if an object could travel faster than the speed of light, it would be travelling backwards in time relative to us. One might think therefore that all a rocket has to do is keep

accelerating until its speed is greater than the speed of light. The problem with this is that as time dilates, space contracts and the rocket's mass increases; so the more massive the rocket gets, the more energy it will need to accelerate. Therefore, it would need an infinite amount of energy to reach the speed of light, which is obviously impossible.

Tachyons are theoretical particles that have never been observed. By definition, they always travel faster than the speed of light, so they never cross the speed of light barrier, which according to the theory of special relativity is impossible. Davies (2002a, p. 110) explains that tachyons possess imaginary mass (in the mathematical sense), so "there is no guarantee that they would interact with ordinary matter, in which case it would be impossible to use them to send signals anyway."

There have been several experiments where photons appear to travel faster than the speed of light, and hence backwards through time (Steinberg, 2000). However, the real test is whether any information can move backwards through time, and so far none have had any success in demonstrating causality violations.

Immediately after the big bang, it has been calculated that the expansion of space accelerated to a speed faster than the speed of light. However, this does not violate special relativity because expanding space does not carry any information. When considering concepts on a cosmological scale, we need to use general relativity instead, which allows for the fabric of space and time to be stretched faster than light (Kaku, 2008, p. 203).

Wormholes

In our universe, there is no theoretical reason why space cannot be curved so that it is folded back on itself. We do not yet have the technology to do this, but to do so would not break any known laws of physics. If a rip in the fabric of spacetime could be made on each side and joined in the middle, then a bridge could be formed which would create a shortcut from one side of the universe to the other as shown in Figure 19. This would allow light to travel between two points in the universe in a shorter time than it would take it to travel the long way round. This is not a violation of special relativity because that only applies locally; in this case, general relativity would apply and this allows for holes in space. Einstein & Rosen (1935) discovered this solution to the

Einstein field equations, and it therefore became known as an 'Einstein-Rosen Bridge' or 'wormhole'.[1]

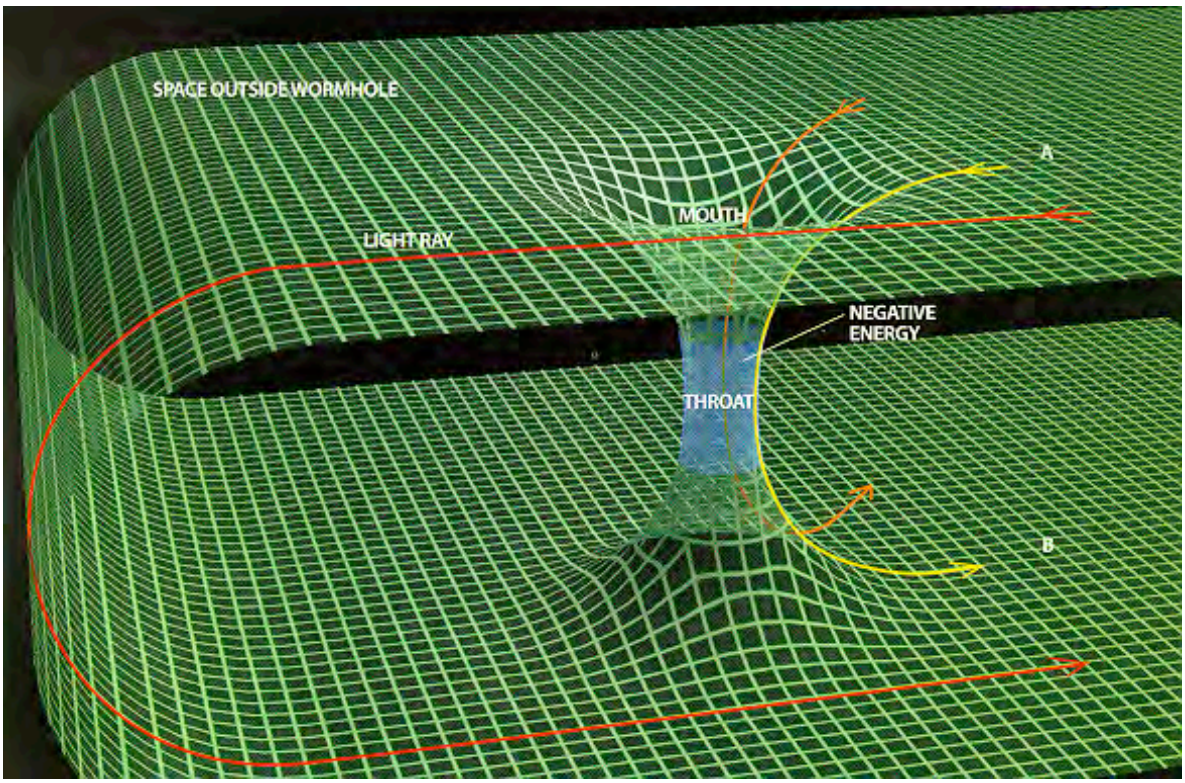


Figure 19: A wormhole in two-dimensional space[2]

There is an invisible circular boundary surrounding the mouth of a wormhole called the 'event horizon', and once it is crossed there is no turning back. The force of gravity inside it is so strong that nothing can escape, not even light, which is why all space inside of this circle appears totally black.

One problem for time travellers is that the gravitational pull increases the closer they get, which will cause their feet and head to be stretched apart. As they pass through the wormhole, their bodies and every atom in them would become 'spaghettified' and ripped apart by the enormous forces of gravity inside. For a wormhole to be traversable, it would have to be designed to keep these forces to a minimum, so that an object could pass through without having its atoms ripped apart.

[1] The term 'wormhole' was coined by John Wheeler.

[2] Drawn by Benji64. Retrieved on 4 Feb 2012 from http://www.universetoday.com/wp-content/uploads/2008/06/wormhole_graphic.jpg.

Another problem is that the throat of the wormhole will close up as soon as it is formed, which means that it would not be traversable. Kip Thorne (1994, p. 486) of Caltech suggests that the throat of a wormhole can be held open if enough exotic matter (negative energy) is applied. The reason is that positive energy gravitates while negative energy anti-gravitates (Davies, 2002a, p. 71). Although exotic matter has never been observed in nature, it remains possible that it exists. So finding and installing enough of it to hold open the throat is not currently a viable option.

Wormholes as time machines

Kip Thorne and his colleagues at Caltech postulated how a wormhole could be used to travel through time as well as space (Morris, Thorne, & Yurtsever, 1988). They suggested that if one of the mouths of the wormhole was made to travel much faster compared to the other one, then when they were brought back together again, relativistic time dilation would have caused an age difference between the two (as in the previous example of twins on p. 53). Another method could be to take one mouth of the wormhole close to a massive object so that gravitational time dilation takes place.

Either of these methods would create a time machine out of the wormhole because passing through it one way would allow you to move forwards in time and passing back the other way would allow you to move backwards in time. The main limitation with this method is that you would never be able to travel back to any date prior to the construction of the time machine.

A wormhole configured in this manner would create a closed loop in spacetime, which in physics is known as a 'closed time-like curve' (CTC) and is a valid solution to Einstein's equations. Wolf (2004, p. 100) explains, "closed timelike lines … are trajectories through space that at first move forward in time, but then curve around and go backward through time, arriving right back where they started at precisely the time they started."

Theoretically, if spacetime was curved enough, the wormhole could be configured, so that you could meet yourself just before you left. There may be parts of the universe where these loops exist naturally, and if they do, then the possibility of travelling back in time might already exist. The laws of physics do not preclude the possibility of you

being able to talk to yourself, touch yourself, or even trying to kill yourself, which if successful, would cause a temporal paradox.[1]

Warp drives

Miguel Alcubierre (1994, p. L73) proposed another way that a spaceship might appear to travel faster than the speed of light in order to travel back through spacetime:

> It is possible to modify spacetime in a way that allows a spaceship to travel with an arbitrarily large speed. By a purely local expansion of spacetime behind the spaceship and an opposite contraction in front of it, motion faster than the speed of light as seen by observers outside the disturbed region is possible. The resulting distortion is reminiscent of the "warp drive" of science fiction. However, just as it happens with wormholes, exotic matter will be needed in order to generate a distortion of spacetime like the one discussed here.

Time travel with superstring theory

The latest version of string theory is called 'M-theory'. The fact that it needs eleven dimensions to work puts off many physicists. However, string theory can be used to build mathematical time travel models that do not rely on wormholes. For example, Dzhunushaliev (2002) showed how the classical string equations for a flux tube with its mouths attached to two D-branes are very close to the corresponding equations for a wormhole between two universes.

Cosmic strings

If cosmic strings exist, spacetime would warp around them due to their enormous mass. These narrow tubes of energy are predicted to stretch across the universe. Goudarzi (2007) proposed that if two such strings moved parallel to one other, they could warp spacetime in such a way that might allow backwards time travel.

Teleportation

Teleportation is a "hypothetical method of transportation in which matter is converted into minute particles or into energy at one point and re-created in original form at another" ("The American Heritage Dictionary of the English Language," 2009). The biggest misconception about teleportation is that it is a way of transporting an object instantaneously from one place to another (Minkel, 2008). If time and space could be overcome in this manner, it would constitute faster-than-light travel and hence time

[1] Temporal paradoxes are discussed more fully in the section 'The Paradoxes of Backwards Time Travel', which begins on page 62 of this chapter.

travel. Although this is what might seem to be happening to an independent observer, teleportation does not do this.

Quantum teleportation is not the same as the common term teleportation because no matter is transported, just information. It is also known as entanglement-assisted teleportation because as well as using a conventional communication channel, it uses entanglement to transmit quantum information non-locally. However, because classical information cannot be transmitted instantaneously, quantum teleportation cannot be used for communication at superluminal speeds, so teleportation alone is not a valid form of time travel.

The technique of quantum teleportation was discovered by Charles Bennett et al. (1993) and involved entangling unknown quantum states before transferring information about them from point A to point B. Physicists started by teleporting photons or atoms, but have now progressed on to teleporting molecules.

Wheeler-Feynman absorber theory

If a charged particle is accelerated in a magnetic field, more inertia can be observed than for an equal mass with no charge. During the early 1940s, John Wheeler gave Richard Feynman this puzzle to solve. Wheeler had already noticed an interesting feature of Maxwell's equations: There were two sets of solutions: one propagating forwards in time at the speed of light (c); the other propagating backwards in time at the speed of light, or we could say forwards in time at the negative speed of light (-c). The latter is a wave with a negative oscillation frequency, ν and hence negative energy ($E=h\nu$). Both travel at the same speed and cover exactly the same distance. He coined the following terms:

- 'Retarded waves', which arrive later than when they set out because they are retarded by "c", so they are a wave of positive energy flowing into the future.
- 'Advanced waves', which arrive earlier than when they set out because they are advanced by "c", so they are a wave of negative energy flowing into the past.

Together they developed the Wheeler-Feynman absorber theory, which states that any emission process makes advanced waves on an equal basis with ordinary retarded waves. The advanced solutions are conventionally rejected as unphysical or acausal, but both waves are valid orthogonal solutions of the electromagnetic wave equation. These

interactions go both ways in time symmetrically because they occur instantaneously as far as our clocks see. To distinguish them, one would have to stand outside of time in a kind of pseudo-time.

Cramer's transactional interpretation of quantum physics

John G. Cramer (1986) published a paper on his transactional interpretation of quantum physics, which built on the Wheeler-Feynman absorber theory. He suggested that the quantum wave represents the probability of a transaction through an exchange of advanced and retarded waves, and that it does not violate causality or free will. He claimed that the paradoxes of the Copenhagen interpretation of quantum mechanics could be resolved just by accepting the following idea: the quantum wave has a second part that is the equivalent of the original, but made of negative energy that travels backwards through time.

Antimatter

Einstein (1905) proposed the mass-energy equivalence equation, which for a particle at rest is $E=mc^2$. For a moving particle, we require an extra term (ρ) to account for the particle's momentum, which gives the relativistic mass-energy equivalence equation, $E^2 = m^2c^4 + \rho^2c^2$. Energy is now equal to the square root of a number, which means that there are two possible solutions for energy, one positive and one negative. This creates a problem for many physicists because it means that every particle could have a corresponding negative energy particle (antiparticle). It would have the same mass, but its charge, if it had any, would be opposite.

Dirac (1928) suggested that an electron, which has a negative charge, could exist with a positive charge if it had negative energy. Three years later he predicted the existence of what he called an 'anti-electron' that would annihilate an electron and itself if they came into contact. In August 1932, Anderson (1933) discovered this anti-electron in an experiment at the Caltech Laboratory in Pasedena, which he eventually named the 'positron'. So the outcome of this was that there would always be two solutions to the mass-energy equivalence equation, one for matter and one for antimatter.

When a sub-atomic particle is moving backwards in time, it behaves exactly the same as its antiparticle moving forwards in time and vice versa. Therefore, an antiparticle moving forward through time is indistinguishable from a particle moving backwards through time. In conclusion, it can be seen that backwards time travel is unproblematic

on microscopic scales; however, the same cannot be said for backwards time travel on macroscopic scales due the temporal paradoxes that it appears to invoke, as discussed in the next section.

Moving backwards through time

Rather than jumping back to a point in the past or creating a loop that takes you to the past, Wolf (2004, p. 6) considers the possibility of moving "backward through everyone else's time stream so that while you see them grow younger and all processes running backward in time – like a movie in reverse – you go on again at a normal rate." At this point, a person could then make different decisions that would change the whole course of their life and the lives of others. There is no known way of achieving this method.

The Paradoxes of Backwards Time Travel

One of the major objections to the possibility of backwards time travel is that it can cause one or more temporal paradoxes; however, in the opinion of philosopher Lewis (1976, p. 145) "the paradoxes of time travel are oddities, not impossibilities."

One of the most famous temporal paradoxes thrown up by backwards time travel is the 'grandfather paradox'. If a woman went back in time and killed her grandfather before he had met her grandmother, this would mean that she would never be born. As she would not have existed, she would not have been able to travel back in time to kill her grandfather. This would mean that he would not meet an early death and would continue to meet her grandmother, so her mother would be born and then give birth to her. Backwards time travel can therefore create a contradiction regarding the time traveller's birth.

Another is the 'predestination paradox'. One scenario involving predestination is when someone goes back in time, and their actions cause an event that later becomes the reason why they originally went back in time. This would mean that they would be predestined to go back in time in order to create a self-consistent timeline. Any changes they thought they were making in the past would be not be changes at all, as they would be creating history just as it was originally recorded.

For example, a woman from this century goes back in time to Germany to try to prevent the holocaust. She kills Adolph Hitler as a newborn baby; however, when she returns back to her present, she is disappointed to find that nothing has changed in the slightest.

This is because while posing as the family nurse, she killed the baby, but replaced him with the child of a psychopathic homeless woman.[1] This paradox raises some questions: What would have happened if the woman had not gone back in time? By trying to stop the holocaust, did she inadvertently cause it? Did she have a choice about going back and committing the murder, or was it predestined that she would do it?

Another scenario involving predestination is when information about the future arrives in the present, either from a time traveller, a dream, a vision, or from someone who is able to see the future. This causes the recipient to change significantly their actions and behaviour to try and prevent the predicted outcome, which end up causing the very outcome they were trying to avoid. The paradoxical question here is: What would have happened if the information had never arrived from the future? Can gaining information about the future change it? Or is everything predestined?

Another temporal paradox that can be set up by a causal loop is the 'ontological paradox'. For example, an old lady gives a man a gift of a watch. He then travels back in time and gives it to her when she was a young girl. She keeps it for many years until she gives it back to him. The watch will then keep going around this temporal loop. The paradox here is that the watch has no past prior to the moment when the time traveller arrives, so there was never a time when it was manufactured. The object appears out of nothing; its existence is only made possible through time travel. This violates the law of conservation of energy, which states that energy cannot be destroyed or created, only converted from one form to another. The second law of thermodynamics (also known as the law of entropy) is also violated. It states that the spontaneous dispersal of energy at a specific temperature of an isolated system increases with time until it reaches equilibrium. This means that the watch will continuously age as it travels around the loop and will therefore stop working and eventually fall apart. Just as the human carrying it is not renewed during his trip back, neither will any object he is carrying, so eventually the watch will not be able to continue around the loop.

This paradox can apply equally to information as it can to objects. For example, a strange old man arrives from the future and gives you an idea for a great new product. You take his advice and spend your life building a successful business empire based on this product, which eventually leads you to develop it into a time machine. Just as you

[1] This was the plot of 'Cradle of Darkness', an episode of the TV series *The Twilight Zone* (2002).

retire, you realise that it is time to travel back and tell your younger self about the great new product. This is all very plausible, as the information about the great new product came back from the future; however, who was its inventor?

Temporal paradoxes like most other paradoxes are caused by false assumptions made due to a lack of information, so these assumptions need to be identified in order to resolve the paradox. Two of the most popular solutions in physics to the problem of temporal paradoxes are: Novikov's self-consistency conjecture and parallel universes:

Novikov self-consistency conjecture

One false assumption could be that the laws of physics would allow the paradoxical actions to take place. Igor Novikov (1983) developed the 'Novikov self-consistency conjecture', which states that if time travel were possible, there must be a law of physics that would prevent time travellers from doing any action that would cause a temporal paradox. This law he argued would allow us to retain a self-consistent universe. So if a time traveller went back in time, no matter how hard he tried, he would not be able to kill his grandfather. Richmond (2003, p. 300) explains, "Time-travelling assassins on would-be paradoxical missions must always slip on banana-peels, or sneeze just before pulling the trigger, etc." We do not live in a world of complete free will, as we are bound by the known laws of physics.[1] The example Novikov gives is that even if he wanted to, he cannot walk up a wall and across the ceiling of a room due to the laws of gravity. So he is suggesting that there must be a law of physics that would prevent the time traveller from killing his grandfather, no matter how hard he tries to achieve it.

Parallel universes

Another false assumption could be that the universe that we live in is the only one in existence. There maybe parallel universes out there that we cannot see or experience. In his book, physicist Michio Kaku (2008, pp. 230-253) discusses three types of parallel universes and states that they "are intensely discussed in the scientific literature" (2008, p. 230). I have summarised his description of them as follows.

a) Quantum Parallel Universes: When a quantum object is measured, the world splits into two parallel realities, where different outcomes can occur. This idea is known as the 'Many Worlds Interpretation of Quantum Physics', and was first proposed by

[1] Refer to the discussion about free will versus free action earlier in this chapter on page 46.

theoretical physicist Hugh Everett III (1957). The existence of parallel worlds was his way of resolving the paradoxes that exist at the quantum level of physics.

b) Hyperspace: Worlds that exist in a higher dimension. This would allow its inhabitants to walk in and out of our universe like deities. Although mathematically possible, there has been no experimental evidence to suggest that movement between these dimensions is possible or that they even exist. Moving in and out of hyperspace does not necessarily involve time travel, or any other temporal phenomenon. If one time traveller went back to a point in time and experienced an event, and another one went back in hyperspace to the same point in time, then they would be experiencing the same event, but the second time traveller would have a perspective, which included an extra dimension.

c) The Multiverse: Our universe co-exists alongside many other universes. The latest version of string theory postulates that the universe itself is a membrane floating in an eleven-dimensional spacetime, along with as many as 10^{100} other universes alongside ours.

If parallel universes exist, can they be detected? The theory of cosmic inflation states that soon after the Big Bang, our universe underwent a rapid period of expansion, like a tiny bubble suddenly being inflated to a seemingly infinite size. One implication of this theory is that the same fate could be happening to other small bubbles of space. Each one would end up creating its own universe in parallel to ours. If one of these large bubbles (universes) were to collide with ours, it could wipe us out, or a more gentle collision may leave a signature on the cosmic microwave background that we would be able to see. So, if astronomers were able to one day identify the signature of such a collision, it would prove that parallel worlds did exist.

Travelling back along the timeline and arriving in hyperspace would not allow for a divergence of the timeline. Similarly, travelling back in time to a multiverse type of parallel universe would not allow for a divergence of the timeline, as you would be arriving in another world that would most likely be completely unrelated to your present world. However, travelling back in time to a quantum parallel universe would certainly allow for divergence of the timeline.

The grandfather paradox would not be applicable if such a parallel world were to exist. Deutsch (1991) suggests that if time travellers went back in time, another timeline

would be created in parallel to the original one at their arrival point. They would then only interact with the world on this new timeline leaving the original one from which they came unchanged. They could kill their young grandfather before he married, if they wished to do so, and they would continue to live in a world where their parents were never born, so they would not get to meet a younger version of themselves. In parallel to this on the original timeline, their grandfather would still be alive, so they would still be born and live to become a time traveller. Deutsch (1997, p. 288) also suggests, "Other times are just special cases of other universes." Note that if the time traveller were to travel forward in time from this point, they would just move forward along the new timeline. Therefore, they would not be able to return home, unless it was possible to then jump between parallel universes.

Not only do parallel worlds resolve temporal paradoxes, but they can also accommodate the block universe model. If one or more spacetime fabrics were recreated in parallel to the original, then multiple alternate futures could exist with each one having its own fixed spacetime with a slightly different but fixed timeline. Each parallel universe could also have its own different laws of physics, but this is another discussion. Because our technology is not advanced enough to be able to detect parallel universes, they remain just a mathematical theory.[1]

Chronology protection agency

When Hawking (1992) was revisiting Gödel's rotating universe, which demonstrates the consistency of time travel within the laws of relativity, "he put forward what amounts to an anti-Gödel postulate" (Yourgrau, 2005b, p. 8).[2] He suggested that on the macroscopic scale (where we exist) backwards time travel must be impossible because of the paradoxes it creates. He argued that a 'chronology protection agency' would prevent closed time-like curves from appearing, thus making the universe safe for historians. However, he did say, "I wouldn't take a bet against the existence of time machines, as my opponent might have seen the future and know the answer" (Bunting, 1996).

[1] Although Deutsch (1997) argues that the outcome of certain quantum mechanical experiments is an indication that parallel worlds do exist.

[2] Gödel's rotating universe was explained in the section, 'A universe without time' on page 51 of this chapter.

Summary

Boyle (2006) writes, “Despite years of debate, scientists still haven't completely ruled out the possibility of going back in time.” Until quantum mechanics and general relativity are unified, physicists will continue to disagree about how and if at all backwards time travel can take place. Deutsch (quoted in a BBC television interview by Bunting, 1996) says, “I myself believe that there will one day be [backwards] time travel because when we find that something is not forbidden by the over-arching laws of physics we usually eventually find a technological way of doing it.”

Psychological Perspectives on Time Travel

This section is not a treatise on psychology, so the scope of the following discussion is limited only to psychology that is relevant to this thesis. For example, I discuss backwards and forwards time travel using the mind as opposed to the body being physically transported back through time.

The perception of time

Humans feel that they have a sense of time, but is this really a sense like our other senses? Le Poidevin (2009) suggests that even if all of our senses were to stop working, we would still notice the passing of time, so it seems that “we do not perceive *time* as such, but changes of events *in* time”. Therefore, if time cannot be sensed, then why does it appear to be moving forward? Wolf (2004, p. 61) suggests that:

> It appears that time is moving, but if you actually look close enough, what you’ll see is one thing vanishing and another appearing. Your mind puts these vanishing and appearing acts together and connects them, and in so doing provides you with your first and primary illusion of continuity, meaning the semblance of past, present, and future.

According to Pöppel (1978) there are five elementary time experiences: duration, non-simultaneity, order, past vs. present, and change. These are not experiences of time as such, they are made by comparing the perception of the present moment with one or more memories. Therefore, humans do not perceive time through their physical senses, as van Wassenhove (2009, p. 1815) explains:

> [S]ensory receptors receive multisensory information *over time*, [but] there is no specialized receptor for the transduction of time…. The perception of time includes duration as temporal lapses between events, ordering events (arguably a necessity to establish causal relationships), assessing simultaneity and temporal coincidence and discriminating temporal rates and rhythms.

Humans notice change between what they are experiencing in their present and what they remember from their immediate past. They are also able to compare what they are experiencing with what they think they are about to experience, which means the they are able to anticipate change that is in their future. This seems to imply that without memory there could be no perception of time.

Life often feels slow and boring for old people; however, the older they get the more quickly years seem to pass. Wearden (interviewed in Smith, 2008) feels that the apparent paradoxical aspects of time experienced in aging can be accounted for by the fewer novel life experiences that older people have compared to when they were younger. He said that this has not been researched in any great detail, but suggests that the fewer new activities there are in a given period, the slower time will seem to pass. However, when looking backwards, that period seems very short because of the low number of new activities, which creates the retrospective feeling that time is flashing past.

The Fact or Fiction survey mentioned in the previous chapter (Osborne, 2011) also revealed that:

> … the older we are, the longer we want to live, with 46.3 per cent of respondents aged 65 years or more listing "reversing the ageing cycle" in the top three areas of science they would like investigated, compared to only 13.2 per cent of 18 to 24-year-olds. Despite this, only 10 per cent of those surveyed wanted science to discover the secret for immortality.

Mental time travel

The ability to project one's mind forwards or backwards in time is known as mental time travel. Suddendorf (1994, p. 30) writes that it "is a fundamental feature of the human mind; without it, technology, language, morality and religion could not have evolved the way they did." According to Suddendorf & Corballis (2008, p. e1) mental time travel has recently become a focus of work in comparative psychology, neuropsychology, cognitive psychology, social psychology and developmental psychology.

Tulving (2002, p. 1) explains, "Episodic memory is a neurocognitive (brain/mind) system, uniquely different from other memory systems, that enables human beings to remember past experiences." Zentall (2006, p. 173) goes further by stating that "humans have the ability to mentally recreate past events (using episodic memory) and imagine

future events (by planning)." Episodic memory is made up of past personal experiences and their emotions, and it "shares a core neural network with the simulation of future episodes, enabling mental time travel into both the past and the future" (Suddendorf, Addis, & Corballis, 2009, p. 1317). So why have humans developed the capacity for mental time travel? Boyera (2008) argues, "Evolutionary considerations suggest that vivid memory and imaginative foresight may be crucial cognitive devices for human decision making."

When the mind shuts down, as it does every night during deep sleep, or for example when the body is in a coma, the experience of space and time collapses and disappears. This was observed by Angelus Silesius, a 17th century philosopher and poet, "Time is of your own making; its clock ticks in your head. The moment you stop thought, time too stops dead" (Silesius & Franck, 2005, p. 39). Without space and time there can be no separation of any kind, as everything collapses into one. Therefore, there can be no distance between objects, and no time taken to travel between objects because there are no two objects that are separate from one another. There are other ways that such a timeless state can be experienced such as some forms of meditation, prayer, mind-altering drugs (both medicinal and otherwise), or even by brain damage; however, as time is not present in these states, no mental time travel can take place. Many past experiences within the episodic memory can only be accessed via the subconscious mind, which is only active during conscious or semi-conscious states.

Dreams

"One of the fundamental conceptual discoveries of psychoanalytic theory is the role of the unconscious mind" (Darley, Glucksberg, & Kinchla, 1981, p. 491). Sigmund Freud (1900-1953) postulated the existence of the subconscious mind, which communicates messages to the conscious mind via dreams. Carl Jung (1875-1961), the founder of analytical psychology, worked with his patients to find meaning in their dreams. Jung (2001, p. 26) writes, "Apart from efforts that have been made for centuries to extract a prophetic meaning from dreams, Freud's discoveries are the first successful attempt in practice to find their real significance." Philosophers too have been discussing the prophetic nature of dreams for a long time: Socrates (469 BC-399 BC) and Plato (428 BC-348 BC) "suggest that dreams can contain prophetic truths" (Dreisbach, 2000). The purpose of dreams is not fully understood, but it seems they can be used to re-

experience the past or to convey a ‘vision’ of the future, thus creating the illusion of time travel.

Visions

A vision is a form of temporary connection with the subconscious mind that is communicating information about the future; the more religious might say it is communicating with a deity of some kind. A vision could take place in a dream, in a moment of quiet, or even in a moment of crisis. It occurs in the mind as a series of visual images with attached emotions and ideas: it could either appear as an accurate description of an event, or as a symbolic representation of it.

One type of vision can be a warning about a future event that is avoidable, or about a fixed future event that can be prepared for. An example of the latter exists in the Holy Bible (Genesis, Chapter 41), when Joseph interpreted the seven fat and thin cows in the dream of the Pharaoh to represent seven years of plenty in Egypt followed by seven years of famine. Two other types of visions are ‘precognition’ and ‘premonition’:

> The term psi denotes anomalous processes of information or energy transfer that are currently unexplained in terms of known physical or biological mechanisms. Two variants of psi are precognition (conscious cognitive awareness) and premonition (affective apprehension) of a future event that could not otherwise be anticipated through any known inferential process.
>
> Bem (2011, p. 407)

So, precognition is the ability to see a future event before it happens; it is a glimpse of the future that occurs when in a subconscious state (such as dreaming or meditation). Premonition, on the other hand, is a feeling that occurs when conscious; it can also be defined as “a strong feeling that something is about to happen, [especially] something unpleasant” ("premonition," 2009).

Bem (2011, p. 407) also discusses nine experiments, “involving more than 1,000 participants that test for retroactive influence by ‘time-reversing’ well-established psychological effects so that the individual’s responses are obtained before the putatively causal stimulus events occur.” He notes that all but one of the experiments “yielded statistically significant results” (ibid.). According to Radin (2006, p. 162) and Schwebel (2004, p. 32), many successful scientific experiments have been carried out that test for evidence of precognition ability. Both authors state that Honorton and Ferrari (1989) found 309 studies published in 133 articles from 1935 to 1987, which

involved over 50,000 subjects in nearly two million individual trials. After blocking and grouping the studies, "30% of the studies were statistically significant (where 5% is expected by chance)." Although the conclusion was that precognition is a "stable and highly significant effect", this is still a very contentious view.

If the definition of backwards time travel is information travelling faster than the speed of light; then, precognition can be interpreted as an example of backwards time travel where information is arriving from the future.

Déjà vu

This French expression when literally translated means 'already seen' and is defined as "the experience of thinking that a new situation had occurred before" (Farlex, 2008). It could be a feeling of having already visited a place that we know we have never been to before, or it could be an occasion that we feel we have already lived through.

> As much as 70 per cent of the population reports having experienced some form of deja vu.… Since deja vu occurs in individuals with and without a medical condition, there is much speculation as to how and why this phenomenon happens. Several psychoanalysts attribute deja vu to simple fantasy or wish fulfilment, while some psychiatrists ascribe it to a mismatching in the brain that causes the brain to mistake the present for the past.
>
> ("What is deja vu?," 2001)

Psychosis

People suffering from a psychosis have at some point lost touch with reality to the extent that they are living out a dream. German philosopher Arthur Schopenhauer said "a dream is a short-lasting psychosis, and a psychosis is a long-lasting dream" (as cited in Kleitman, 1987, p. 106). The frequency of psychotic episodes can vary enormously, but "most people are able to recover from an episode of psychosis" (Sane Australia, 2005). Symptoms are usually confused thinking, delusions and hallucinations.

> People can develop post traumatic stress disorder (PTSD) when they have been the victim of, or witness to, a traumatic event.… One of the main symptoms of PTSD is re-experiencing the trauma. People get vivid 'flashbacks' that can include seeing, smelling, hearing and feeling things that were part of the trauma. These intrusive memories feel real, as if they are happening now.
>
> (Mental Health Care, 2011)

When re-experiencing a traumatic event from their past a person may believe that by changing something in their past during one of their psychotic episodes they could

cause the following events to change for the better, thus creating a new and different past and present for themselves and those around them. Andre (2003) suggested that a new disorder in the 21st century would be 'temporal psychosis'.[1] However, this is a lay opinion and not apparent in the formal literature.

Regression therapy

Regression therapy works on the basis that anything that has ever been experienced is recorded somewhere in the subconscious mind. Hypnosis is one way of communicating with the subconscious mind and accessing these lost memories. A practitioner of hypnosis uses instructions and therapeutic suggestions to place his subject in an altered state of consciousness. The subject can then achieve mental time travel, as the practitioner guides them to the past or the future. Self-hypnosis can also be used, which is when the practitioner induces himself into such a hypnotic state.

The concept of linear time in psychology is intrinsically linked to causality, change, process and behaviour (Kerr, Bobo, Walls, Filek, & Alpert, 2000). Some clinical schools of thought, using the cause and effect model, view the first event in a series of related events as the most important when addressing present day emotional problems. So guiding a patient back to their past can be an important tool.

The timeline holds a collection of memories, decisions, experiences (good and bad) over time (James & Woodsmall, 1988, p. 15). 'Time Line Therapy' is a form of hypnosis that uses mental time travel: the therapist induces the subject into a light trance and takes them back or forward along their timeline to view a chronological layout of events in their past or future. It is possible for them not just to view these events, but to also step into them and experience the associated feelings and emotions. Although the subject's body is sitting motionless in the chair, their mind is experiencing another time and place. This form of mental time travel "utilizes a person's own internal 'Time Line' to work with their unconscious minds in a variety of ways; including healing emotional traumas and eradicating unwanted thoughts, emotions and behaviors" (James, 2009).

[1] This same term was used to describe a fictional illness of the nervous system in 'Relativity', the 24th episode of the fifth season of the TV series *Star Trek: Voyager* (1999).

Head injury

A traumatic brain injury can be a result of a trauma to the head, but most do not cause permanent, or long-term disability.

> The terms acquired brain injury (ABI), head injury, or acquired brain damage (ABD) are used to describe all types of brain damage, which occur after birth. Acquired brain injury is not to be confused with intellectual disability. People with a brain injury may have difficulty controlling, coordinating and communicating their thoughts and actions but they usually retain their intellectual abilities.
>
> (Brain Injury Association of Queensland, 2009)

All of these can cause cognitive, emotional, and behavioural difficulties, which may result in the victim exhibiting what appears to be psychotic behaviour. The victims may have thought that they experienced a trip into their past, or future, or even into a timeless dimension. As mentioned in the prologue of this thesis, the latter was a personal experience of mine, which was one of my motivations for choosing this area of research.

Some of the following types of mental time travel are based more on popular psychology than on scientific psychology, but are still types of psychosis.

Waking up in another time or place

There are many forums on the internet where people speak of their experiences of spending time in times or places such as parallel universes. The famous author Whitley Strieber has published books about his experiences in parallel universes. In his 'non-fiction' book, *Breakthrough* (1995), Strieber takes a jeep ride with a boy and ends up in an alternate universe. These experiences can never be verified by scientific experiment; however, this has not stopped novels and films being produced that use waking up in parallel universes or in another era as a plot device to show what life would have been like if a different decision had been made at an earlier point in time. The unanswered question is: Are these experiences symbolic visions, glimpses of another world, which is as real as the one we experience day to day, or neither?

Religious experiences

Angels in the Holy Bible are the messengers of the supreme deity. Odajnyk (2009) states that the word comes from the Greek *anglos*, a translation from the Hebrew

mal'akh, meaning 'messenger' and goes on to write about angels from the point of view of Jungian psychology:

> As messengers, they represent attempts on the part of the Self to convey information to ego consciousness that otherwise would not be understood or apprehended. Their manifestation in human form allows for an empathic connection and makes the messages they convey comprehensible to human beings. As intermediaries between the divine and human realms, angels are attempts on the part of the transpersonal unconscious to maintain a relationship with human consciousness and to participate in the personal and temporal world.

Many religions and civilisations have a shared belief in these messengers. "There are angels in Zoroastrianism, in Buddhism, in Taoism. ... Shamanistic practices have their own intercourse with winged beings, though often they come in the form of eagles or ravens or spirits that we don't associate with Christian iconography" (Burnham, 1990, pp. 27-28).

Angels can move between our world and an atemporal world; they are purported to be able to show humans their past, future, or even an alternate reality. For example, angels appear in several places in the Holy Bible, but in the Book of Revelations, "Angels show John future events in symbolic form - Rev. 14:6-9, Rev. 17:1-2, Rev. 18: 1-4" (Warren, 1997).

Reasons for wanting to time travel

Research has taken place to discover who would like to time travel and why. In his study about the perception of time, Cottle (1976) shows that 36% of respondents were willing to pay $10,000 to purchase a year of time travel to a period before they were born. He further showed that if such trips were free, the interest was almost universal. In 1988 the editors of *Seventeen*, a magazine read by teenage women, conducted a poll about time travel.

> Published in the March issue, the 'Best of Times' opened with the provocative question, 'Given a trip in a time machine, where would you get off?' The answers ranged from Troy 1200 B.B to Victorian England, to the "so cool Fifties"… their responses show they view the past as a romantic "place".
>
> (Nahin, 1993, p. 3)

Smith (1985) observes, "the popular appeal of time travel … is no doubt due to a nostalgia for the past, which is almost an omnipresent aspect of the human condition." Westfahl (2002, p. 1) adds that one foundation of fantasy appears to be a longing to

return to romantic or idealized past eras, accompanied by the sense that the passing of time has brought only decline and degeneration.

In Back to the Future (1980), Doc Brown's reason for wanting to travel through time is simply "for the thrill of adventure, and because it hasn't been done" (Silverman, 2011). However, for those without the technology to actually do it, their reasons might be different.

Persinger (1985) hypothesizes that omnipotent and eternal themes concerning one's personal universe are used as cognitive mechanisms for reducing anxiety. Results of a longitudinal study by Persinger & Makarec (1990) strongly suggest that due to the increasing success of science and the education of the public, exotic beliefs such as time travel and mystical forces may serve as substitutes for more traditional religious concepts.

Pelletier (2008) suggests that some more popular reasons for wanting to travel through time might include the following:

1) Glimpsing into the future could allow us to become aware of dangerous threats in plenty of time to find solutions.

2) Backwards time travel would enable us to scan minds of lost loved ones the night before they died, and with tomorrow's technology advances, allow them to continue living in our future time.

One reason for wanting to make a return trip to the future could be for financial gain, by learning what was about to happen on the stock exchange for example. Another might be for military gain, by bringing back advanced weaponry from the future; however, it would be important to bring back the knowledge of how to use it – if not, the consequences could prove to be fatal. There is an example of this in the time travel film *Philadelphia Experiment II* (1993), in which a stealth bomber was not flying high enough when it dropped an atomic bomb, and got destroyed by the mushroom cloud.

Lowenthal (1999, p. 22) suggests five reasons for travelling back in time:

- explaining the past,
- searching for a golden age,
- enjoying the exotic,

- reaping the rewards of temporal displacement and foreknowledge, and
- refashioning life by changing the past.

In addition, Kerr et al. (2000) mention the following motives for going back in time:

- escapism,
- quest for identity,
- love, and
- power as manifestation of free will.

'Explaining the past' could be motivated by inquisitiveness about what really happened in our past. Rascaroli (2001) writes, "The possibility of meeting ourselves, of gazing on ourselves from the outside is the paradoxical event that perhaps fascinates us most in all the narratives on time travel, both in literature and in cinema."

'Refashioning life by changing the past' could be when a person would like to rewrite parts of history, but not everyone thinks this is a good idea. In 2011, the Chinese government banned all depictions of time travel on Chinese television. "Time travel is on the list of activities that have been banned for scriptwriters and directors since March 31" (Hartley-Parkinson, 2011). The main reason for the ban given by the State Administration for Radio, Film & Television is that "the producers and writers are treating the serious history in a frivolous way, which should by no means be encouraged anymore" (Ho, 2011). They also rule, "TV dramas shouldn't have characters that travel back in time and rewrite history [because] this goes against Chinese heritage" (Yoon cited in Voigt, 2011).

Changing the past could also be motivated by personal regret: going back to correct a mistake in order to remove the feeling of self-blame. Psychotherapist Constance Kaplan interviewed in the documentary *The History and Allure of Time Travel* (Lipsius, Miller, & Strom, 2004) comments:

> Is there a human being who doesn't wish to go back in time and to correct a mistake, to undo a loss, to redress a humiliation, and to control what comes next? ... I think the allure of time travel stories has to do with the illusion of manipulative control that we all get to use as a defence against helplessness in a world where we can't really control the outcome of our own actions and our own choices much less the outcome of the behaviours and the choices and the actions of other people.

Psychotherapist John D. Birac, (interviewed in Magallon & Strom, 2004) says, "We often think about control in our lives … we have to make choices moment by moment in order to make sense out of the chaos into which we are thrown." Many dictionaries define 'chaos' as being "complete disorder and confusion". However, some behaviours that appear to be completely random and chaotic can be predicted using what scientists call 'chaos theory'.

Chaos Theory and Time Travel

If time travel to the past were possible and a person took a return trip to their childhood to change something, then on their return to the present, would this have made a difference? Chaos theory suggests that the consequences of the action in the past would depend on how significant the change was, and also where and when it took place. The classic example is that the flap of a butterfly's wings in Brazil could cause a tornado in Texas - or not.

While working as a researcher at MIT in 1961, meteorologist Edward Lorenz created a simple weather forecasting model using a software program with 12 equations. He noticed that the slightest change in his input data would give very different long-term weather predictions. Such systems are known as 'nonlinear systems' and are normally characterised by long-term unpredictability. Lorenz's paper (1963) sparked a revolution of interest in the subject, and from out of this grew the field of what is now called chaos theory (Vaughen, 2008).

If the output of one stage of an event is continuously fed back to its input and to the input of the next stage, then the event will quickly become unpredictable and appear chaotic. An event is considered chaotic when the time period over which an accurate prediction can be made is limited by the lack of enough detailed information about the original event. Figure 20 shows what happens when the initial conditions for a complex system are modified by only the smallest amount.

The red and blue lines follow each other very closely at first, and then they begin to drift apart before soon following very different paths. The position of the particle is only shown in one dimension against time here. In a three-dimensional model their paths may never meet again, even in a bounded system such as the one in Figure 20.

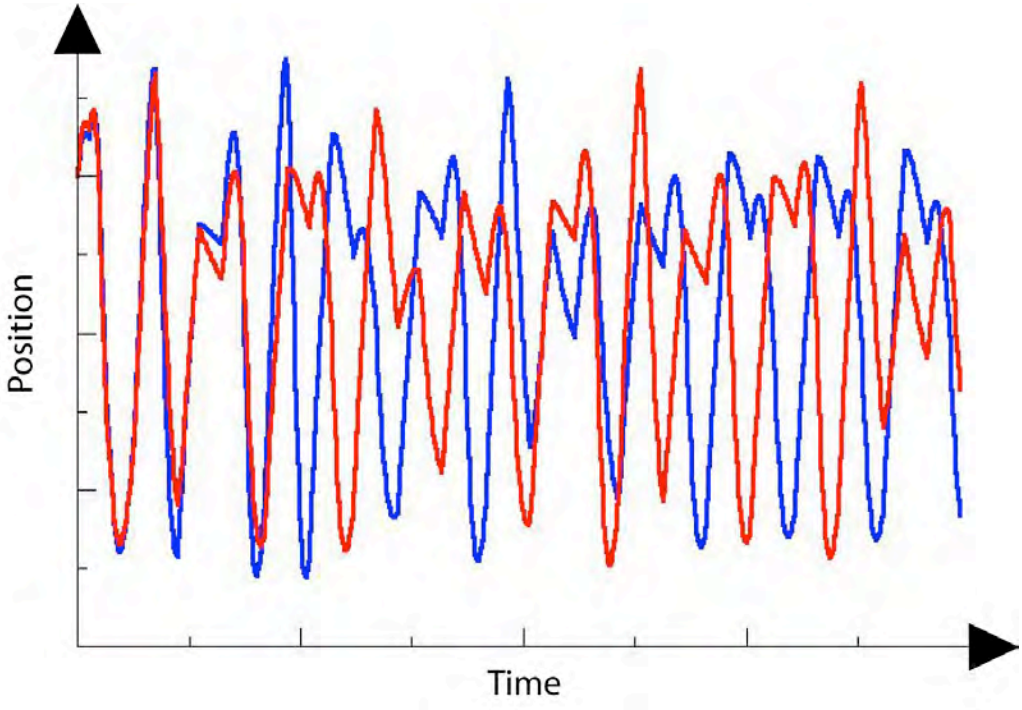


Figure 20: Position against time of two moving particles in a bounded complex system with only slightly different initial conditions imposed[1]

This effect is an example of what scientists call 'sensitive dependence on initial condition'. Lorenz (1972) presented an academic paper called, 'Predictability: Does the Flap of a Butterfly's Wings in Brazil Set Off a Tornado in Texas?' and since then the effect has been more commonly referred to as 'the butterfly effect'.

The butterfly effect can best be visualised using a 'phase space diagram', which plots an object's two-dimensional position against its associated velocity (or momentum) to create an abstract space that physicist call 'phase space' (Trump, 2009). Although time is not represented on either axis, the distance travelled along the plotted line represents time, so the object's position and momentum can be tracked over time.

This line will be attracted to certain specific points on the graph and these are known as 'attractors'. There are four main types of attractors that can exist in phase space:

- Simple loop (exhibits periodic motion)
- Doubled loop (exhibits quasi-periodic motion)
- Point attractor (exhibits damped harmonic motion)
- Strange attractor (exhibits chaotic motion)

[1] Drawn by author.

If an object moving with periodic motion in phase space were plotted, the phase space diagram would show a simple loop: an orbit about the origin of the graph with different sized orbits representing different periods as shown in Figure 21.

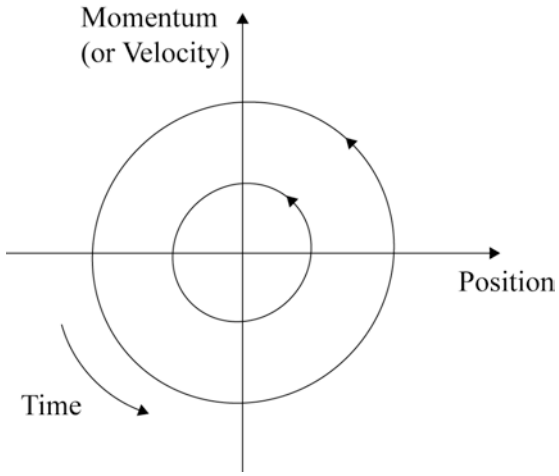


Figure 21: Phase space diagram for the simple harmonic oscillation[1]

As a damped pendulum is a dissipative system, it will come to rest over time. This is known as a point attractor and can be represented on a phase space diagram by an orbit that spirals in to a central point, which is a type of 'point attractor' as shown in Figure 22.

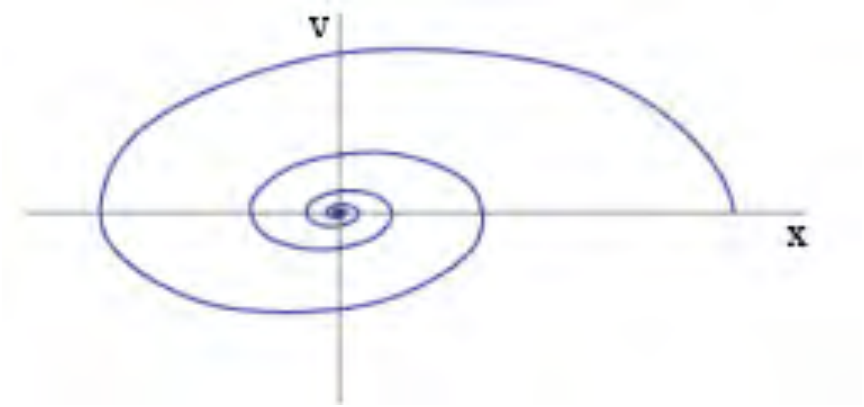


Figure 22: Phase plot showing momentum as a function of position for damped harmonic motion[2]

[1] Drawn by author.

[2] Drawn by author.

Strange attractors on the other hand can have great detail and complexity. The path can tend towards infinity at different rates or toward zero, even though the initial points are very close together. The famous Lorenz attractor comes from his simple three-dimensional model of a weather system. It is one of the most complex chaotic system diagrams and resembles the wings of a butterfly, as can be seen in Figure 23.

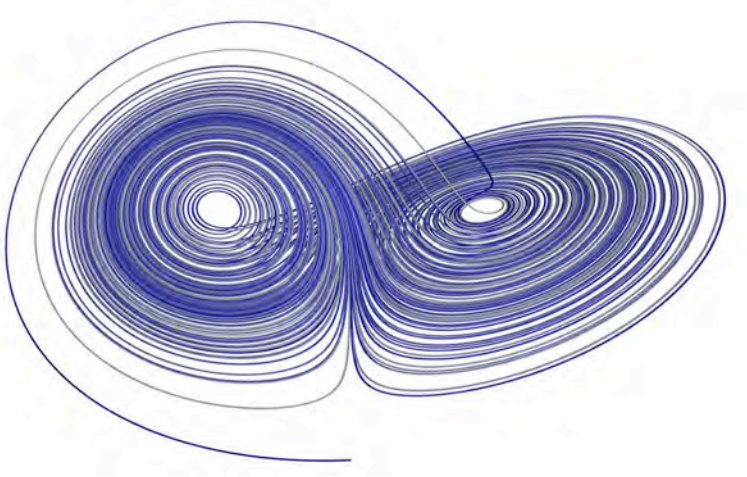


Figure 23: Phase space diagram for the Lorentz strange attractor[1]

There are two strange attractors present. As can be seen, a small change could result in a shift to the other attractor, or it could result in spiralling around the same attractor. If you were watching the particle moving, it would appear to move across to the other attractor at random points in time, in other words, its motion would appear to be chaotic. However, as it is a complex system, the more accurately you knew the initial conditions the more accurately you could predict the motion of the particle. This is the nature of the butterfly effect, and it is how complex systems such as these only *appear* to be random.

An example of a strange attractor can be seen in the weather. Temperature, humidity, wind speed, and air pressure are all sensitive to initial conditions. As they feed back on themselves and interact with each other they produce complex behaviour, so it is hard to forecast the weather more than a few days ahead. The weather, however, remains within a broad band of a strange attractor we call 'climate' (Sardar & Abrams, 2008, p. 146).

[1] Retrieved 24 April 2009 from http://www.igi.tugraz.at/legi/lorenz_attractor.jpg

Chaos theory in psychology

Scientists working with chaos theory are now able to look at nonlinear systems that were once considered to be totally chaotic and find predictable patterns within them. Examples of such systems that have been seen in the stock market, evolution, and physics "are beginning to be applied to psychology by researchers from cognitive, developmental and clinical psychology" (Ayers, 1997, p. 373).

For similar reasons to weather forecasting, it is not possible to make accurate long-term predictions about how people will behave. Although their behaviour is complex, it is not random, so it will usually remain within a broad band of a strange attractor known as 'personality'. Therefore, it should be possible to predict how a person of a particular personality type would behave given certain circumstances, but it would be impossible to see the long-term ramifications of that behaviour.

> Chaos theory in psychology is not that different from the physics viewpoint - except that we have the human component…. Chaos theory, if it were linear, would be very easy to deal with in terms of psychotherapy, but it's not linear; it has to do with a tremendous, infinite and complex number of things within the system that occurred back at that time…. Without a doubt, chaos is a natural state of affairs for human beings.
>
> (Birac interviewed in Magallon & Strom, 2004)

Birac went on to say that chaos is not necessarily bad. If we can acknowledge that we live in a chaotic society, then all we need to do is to stay in the moment and go with the flow. He tries to show his patients that it is a futile exercise to "attempt so much control of what might be in the future."

This brings us back to the conversation of determinism versus free will. Sappington (1990) reports that a large group of psychologists are now applying the concepts and/or methodology of chaos theory to philosophical issues such as determinism and free will. Farmer (as cited in Gleick, 1987, p. 251) suggests that chaos theory could be a way to reconcile free will with determinism because although the system is deterministic, you cannot say what it is going to do next.

Backwards time travel with the Butterfly Effect

If a time traveller went back in time, his arrival could cause a string of events which might cause the course of history to change, or not, depending on when and where he arrived and what he did. This would mean events could head towards another outcome (strange attractor) or return to the original. In a phase space diagram for the Lorentz

strange attractor (as shown in Figure 23) this would be akin to moving to the other wing of the butterfly, or not.[1] Just the slightest flap of a butterfly's wing at one particular place and time could cause the timeline to diverge, thus creating a new future, but at a slightly different place and time, it might make no difference at all to the future. In this case the time traveller may need to make a more significant change in the past for the course of history to be changed.

Summary

I looked at the different theories described by physicists and philosophers about the nature of time as well as backwards and forwards time travel. Possible solutions to temporal paradoxes such as parallel worlds and self-consistency were discussed. I also looked at some psychologists' perspectives on mental time travel, as well as possible reasons for wanting to time travel. Finally, I discussed the physics of chaos theory and how the butterfly effect could be applied to psychology as well as to time travel.

In Chapter Four, I will explain how I compiled a list of time travel films, and how I reviewed and categorised them to elicit a number of models of time that are depicted in films involving time travel.

[1] In reality, there could more than just two attractors.

CHAPTER FOUR: FILMS

> *The theory of relativity and cinema do have something in common: a fatal attraction for time travel.*
>
> - Laura Rascaroli, author and university lecturer[1]

The main research question addressed in the study of this chapter is: 'What models of time travel can be constructed from films?'

The aims of this chapter are:

1. To create a list of films involving time travel.
2. To categorise the films in relation to the different ways they portray time.
3. To uncover a set of models of time travel used in films.
4. To identify which of these models filmmakers did not use in their films.

Scope

The scope of this study had to be sufficiently large to encompass a range of films, but narrow enough to make it manageable. I chose a target sample size of 100 films to review, so there would be a large enough data set from which to draw meaningful conclusions. By the end of my research I had identified 444 films involving time travel and other temporal phenomena, and had reviewed over 100 of them, which did not include TV shows or short films. In order to separate out the short films, I chose to exclude films with a running time of less than 80 minutes. I decided to include foreign language films because I thought my data would be richer for their inclusion and there were not too many of them. I defined temporal phenomena to include time travel as well as films where the timeline changed, i.e. it slowed down, sped up, stopped, reversed, fast-forwarded, or even split into two.

Different models of time began emerging as I watched the films, and there were new time travel films being released all the time during my research, so I had to choose a cut-off date for my data set. I chose the end of 2008 because, by this time, I had surpassed my goal of reviewing and categorising 100 films, and no new models of time

[1] Rascaroli (2001).

were emerging from the film reviews. During 2009 I still watched, reviewed and categorised other films involving time travel, but did not include them in my original data set, which closed after the one hundredth film review.

Overview

This chapter includes a methodology section describing the method that was used for my research. The results and analysis section identifies the different film genres within time travel, as well as the different past-future rules and the different types of timeline used by the filmmakers. It also contains a full review of a time travel film as an example of how I reviewed each film that I watched. There then follows a table of results summarising the models of time for each of the 100 films that I reviewed. The discussion section looks at the number of films that use each of the past-future rules and each timeline. It also discusses how these properties can be combined to create models of time. I conclude with a summary of the different possible models of time noting which ones were used in the films reviewed and which ones filmmakers did not use in their films.

Appendices I and II, which should be read in conjunction with this chapter, include the following extra information:

Appendix I contains a two-page review of each of the 100 films that make up the data set, followed by a description of how I decided which model of time was being used. Each review finishes with one or more diagrammatic representations of the film's timeline.

Appendix II contains all the films that were excluded from the data set. More than fifty reviewed films were not included in the data set for a variety of reasons, and these reasons are explained in this appendix. Each of these films has a three-line review, followed by a brief comment and the model of time used. The second half of this appendix lists films that were identified as potentially involving time travel, but were not reviewed because I was unable to rent or borrow them.

Methodology

In order to find out what models of time existed in film, I could either have proposed a hypothesis to test, or I could have started reviewing the films to see what models emerged. I had not seen any time travel films in the previous few years, and had only

seen six of them in my life.[1] Between them, these six films involved a time machine, a time loop, an angel, a wormhole, cryogenic freezing and parallel lives. Therefore I had a rough idea of the kind of temporal phenomena that existed in these types of film, but certainly carried no preconceived ideas into the study about what models of time I was going to find. Therefore, I was unable to come up with a hypothesis, so I started watching the films.

My research method involved writing a detailed review of each film that I watched - not of the plot, but of how temporal phenomena were treated in the plot. I then extracted data from these reviews, which I used to categorise the films, from which I expected different models of time to emerge. Initially, I did not know how many of these films existed, or how many I would need to watch, but I knew that if I watched enough of them, some models of time would eventually emerge from all of my viewings that that I could test. After reviewing more than fifty films, some models of time began to emerge, but I continued until I reached my goal of 100 film reviews, as by then no further models of time were emerging.

Selection criteria

My research soon revealed that there were hundreds of these films, far more than I had originally anticipated. I therefore had to start thinking about ways of narrowing the scope of my thesis. The criteria that I chose for this purpose had to be measurable and easy to work out.

I had decided on a criterion that a film had to be a full-length film, as opposed to a short film, which I defined as being at least 80 minutes. It did not matter if it was a cinema release, a made-for-TV film, a straight-to-video film, or straight-to-DVD film. The runtime was generally written on the case of each film that I watched; however, some films did not have a case, so I looked up the runtime on the Internet Movie Database (IMDB) website.[2] Where the length of the film varied from country to country, I used the runtime of the Australian release and if that was not available, then the runtime of the USA release, or if not, then the UK release. When I reviewed the director's cut of a

[1] Back to the Future (1985), Groundhog Day (1993), It's a Wonderful Life (1946), The Philadelphia Experiment (1984), Sleeper (1973), and Run Lola Run (1998).

[2] http://imdb.com

film on DVD, the runtime was often different from the cinema release, so the runtime I used was for the version I had watched, which was not necessarily the original version.

I could have narrowed the scope of my study by excluding the foreign language films from my data set, but this would have only reduced it by about five per cent. Many of these films were very popular and interesting to analyse, so I concluded that my data would be richer for their inclusion.

I also needed to clearly define 'time travel and other temporal phenomena'. I chose to base my definition on the one given by David Lewis: "An object time travels if the difference between its departure and arrival times in the surrounding world does not equal the duration of the journey undergone by the object."[1] Cryogenic freezing would therefore fit within this definition; however, I had to expand this definition so that it was not just restricted to just an object: it had to include both information and also the mind travelling through time.[2]

As for temporal phenomena, the definition I used here was that the timeline had to change, i.e. split into two, slow down, speed up, stop, reverse, or fast-forward compared to the normal progress of time. Immortals, or people who aged at a different rate to those around them were excluded, as I considered this a biological phenomenon rather than a temporal one.

Creating a list of films

As mentioned in the introduction to this chapter, my initial research identified hundreds of films that fit my criteria. They were mainly sourced from using the IMDB website. Their list is continually growing as more reviewers add tags to films, so I had to continually check it for new titles throughout my thesis. When using the 'Advanced Search' feature to filter by 'feature film' OR 'TV movie' OR 'video' AND with a keyword of 'time-travel' AND a runtime of at least 80 minutes, there were 333 films listed.[3] It was interesting that when I filtered these films to include only films with at least 1000 votes, the number of films dropped to 131. This told me that over 200 of the films were going to be very hard to find. If so few people had rated them on IMDB,

[1] This definition was first used in the section, 'Forwards Time Travel' on page 52 of Chapter Three.

[2] Refer to the section, 'Mental time travel' on page 68 of Chapter Three.

[3] As of 3 March 2010.

then the film was either not very popular, or was probably very old and had never been commercially released on DVD or VHS. Also there were films on this list that were incorrectly tagged as 'time travel', or for example, had been tagged because someone in the film mentioned the topic, not because time travel had taken place in the film. There were a surprisingly large number of films missing from their list though because my final list of films involving time travel contained 444 films.

Another source of films came from friends and colleagues, who often suggested films that were not on my list, as did members of the audience when I was giving a talk about my thesis. Many of the other films came while researching the following websites at various times between January 2007 and December 2009:

- The Big List at Aetherco's Online Time Travel Guide
  http://www.aetherco.com/timelinks/timevideo-thebiglist.html
- Andy's Anachronisms Time Travel Movies
  http://www.timetravelreviews.com/movies_list.html
- Wikipedia List of Time Travel Science Fiction
  http://en.wikipedia.org/wiki/List_of_time_travel_science_fiction
- Time Travel: 120 Movies And TV-Movies About Time Travel Or Time-Loops
  http://www.magicdragon.com/UltimateSF/time.html
- Temporal Anomalies in Time Travel Movies
  http://www.mjyoung.net/time/
- Top Time Travel Movies
  http://www.toptimetravelmovies.com/time/alphabetical_list.cfm/
- Steven's Time Travel Page (no longer exists)
  http://users.metro2000.net/~stabbott/timetravel.htm
- Time Travel movies, 1896-2012
  http://krabat.menneske.dk/kkblog/2010/07/30/timetravel_movies_from_1896_and_on

Sourcing the films

I started by watching as many films from my list that I could find at local video stores, as well as local and university libraries. Any new releases were watched at a cinema. The popular films were easy to rent, but some of the older ones were difficult to locate. Not all the films I was trying to rent had been released on DVD; as they were still only available on VHS, I had to find a shop that rented videotapes.[1] My next strategy was to

[1] Electric Shadows Bookshop, Shop 2, 40 Mort Street, Braddon, ACT 2612.

join an online DVD club.[1] It posted me out two films a week to watch, and after less than one year, I had exhausted their supply of films involving time travel.

Writing the film reviews

When a DVD arrived, my method was to watch it straight though without pausing or rewinding it to take notes. My purpose for doing this was to get a feel for the story and how time was being treated without over-analysing it. I then always watched all of the bonus material on the DVD, such as the documentaries about the making of the film. Most of this bonus material was irrelevant to my thesis, but every now and then, I would pick up a gem of information that I had not noticed when watching the film. I would then go back and watch the film a second time, pausing or rewinding so that I could take notes to help me write the review. I would then type up the notes into sentences, which was often several pages long, thus creating a written review of the film. As I had most of the films for a week, I would usually wait a few days and then watch the film for a third time, often with the director's commentary switched on if it was available. Most of the comments were usually about production issues, but when not much was happening in the film, they would often talk about aspects of the story that involved time travel, or discuss other concepts that were of interest to my study. Every film was different: some DVDs had no bonus material to watch while others had several documentaries. I did not initially know what I was looking for, so I would note every aspect of the film that involved time travel. The more films I watched, the easier the process became because I was seeing plot structures that I had previously analysed in other films. Table 1 shows the breakdown of a typical film that I reviewed.

Analysing the film reviews

As I wrote the review for each film I could see which film genre it belonged to, but was not able to elicit any models of time. Therefore, I considered various software tools that were available to help me find themes and extract meaning from the film reviews. I ended up choosing the qualitative research software package, NVivo.[2] It helps "to manage, shape and make sense of unstructured information … it provides a sophisticated workspace that enables you to work through your information" (QSR International, 2007). I used the tools for classifying the films, as well as sorting and

[1] http://www.quickflix.com.au

[2] NVivo Version 8 by QSR International Pty Ltd, Doncaster VIC, Australia.

Analysis Process	Time to complete (on average)
Watch film	100 mins
Watch bonus material	30 mins
Second viewing of film taking notes	130 mins
Write up notes into a long review	60 mins
Watch with the director's commentary switched on	100 mins
Edit notes down to about 200 words	60 mins
Write an overview of the film	30 mins
Formulate my comments	60 mins
Deduce the model of time	60 mins
Draw graphical representation of the timelines	30 mins
Total	660 mins = 11 hours

Table 1: The breakdown of the time to complete a typical review of a film

arranging information to identify themes that could be combined for building different models of time.

The structure of the models of time emerged while I was watching the films. After watching about 80 of the films, all the models had emerged, and it became easier because I knew exactly what to look for: it was just a case of selecting the correct model of time for each film from a list of existing models. However, the time taken to deduce the model of time still varied enormously. Some films were quicker because the plot was really straightforward while other more complicated plots could take days or weeks of deep thinking for me to analyse which model of time was being used. This process sometimes involved discussions with one of the advisors of my supervisory panel.

By the end of December 2008 no new models of time were emerging, so I was confident that I had elicited all the different models of time and I closed my data set at exactly 100 films.

Most of the information that I had gathered on each film was superfluous to determining which model of time was being used, so I was able to cut down the film reviews in this thesis to only the relevant information. I found that I could include everything that was relevant to each film in just two pages, and these 100 reviews appear in Appendix I. The

first page of each of these reviews is objective; it includes factual information about the film and a synopsis - not of the plot, but of how temporal phenomena were treated in the plot. The second page of the review is subjective; it includes the genre where I placed the film, my general comments and then a brief discussion about which model of time I felt was being used and why. In the Results and Analysis section, a full-length review of *Donnie Darko* (2001) is shown as an example of how a review looked before it was cut down to two pages.

Films that were not included in this data set are listed in Appendix II with an explanation of why they were excluded. For example:

- Some films I watched were labelled as involving time travel on various websites; however, after reviewing them I deemed their time travel content too ambiguous for them to be included in my data set.

- Before the decision was taken to separate the 'full-length' films from the 'shorts', I had already reviewed several short films with a run time of less than 80 minutes.

- There was a delay in getting hold of certain films for various reasons, which meant that I did not get to watch these films until after the deadline of 31 Dec 2008 had passed:

- I continued to watch and review new films released from January 2009 onwards in case one of them was using a model of time that I had not yet discovered.

- After the deadline, I watched some films again that I had seen before I began this research, and discovered that time travel was indeed involved, so they could have been included in my data set.

- I sometimes decided that the plot of the original version of a film was too similar to its remake to warrant them both to be included as separate entries in my data set. For example, I discovered that there were more than twenty full-length film adaptations of the book *A Christmas Carol* by Charles Dickens.

- 290 other full-length films were identified as potentially involving time travel; however, as they were unavailable to watch, it was not possible to verify that, or to write up a review of them, so they were not included in my data set.

Results and Analysis

One of the first observations I made was that there was a rapid rise in the number of time travel films produced. However, when I plotted the 444 films that I had identified against five-year intervals as shown in Figure 24, the rapid rise only took place up until the turn of the century when the numbers began to fall again.

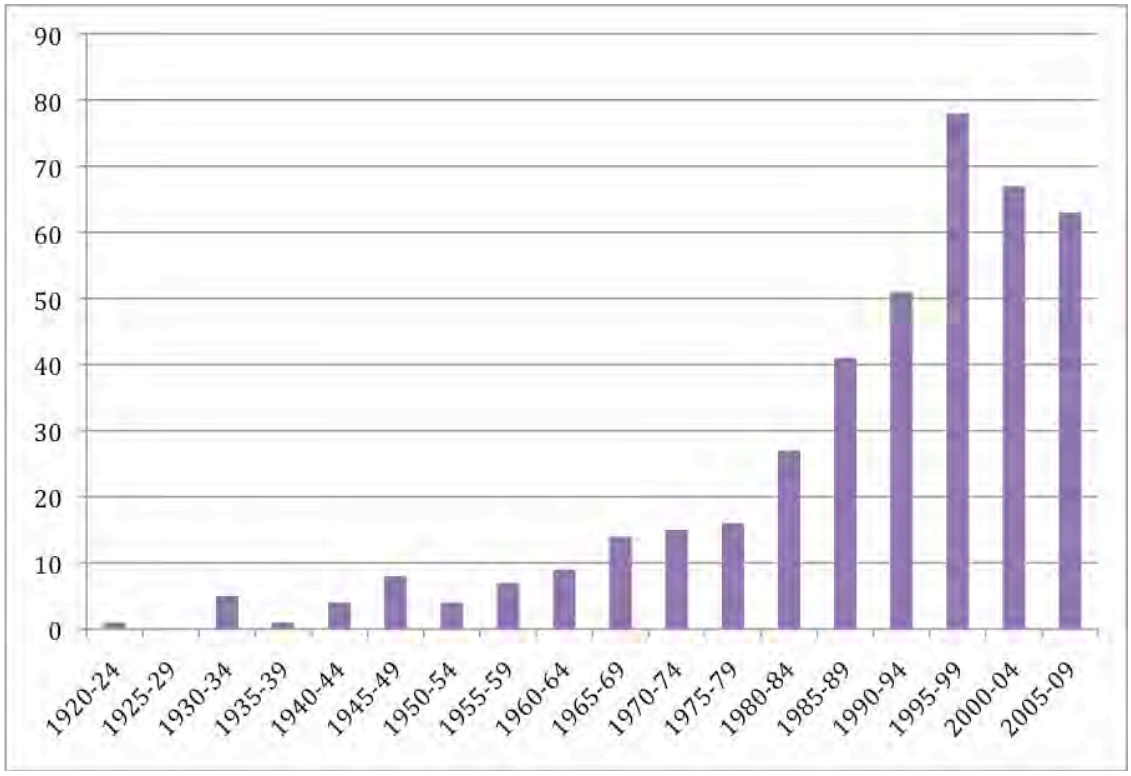


Figure 24: The number of time travel films released in each five-year block

It is too early to confirm whether the genre has passed its peak, but it seems to be a possibility.

Film genres

The films that I reviewed fell into three different mutually exclusive film genres. The number of films is shown in brackets:

- Science fiction films (60)
- Psychological films (20)
- Fantasy films (20)

Within each of these genres, I observed that different types of time travel were taking place.

The majority of the films (60) belonged to the genre of science fiction films. The rule I made for a film to be classified as belonging to this genre was that some science or technology was used to explain how the time travel took place, such as a wormhole or a time machine. The number of times that each type of time travel was used appears in brackets; however, the figures add up to more than 60 films because sometimes more than one type of time travel took place in a film.

- Transporting body through time (18)
- Time travel vehicle (18)
- Creating wormholes (10)
- Finding portals (7)
- Cryogenic freezing (7)
- Hand-held time travel device (3)
- Time reversal (2)

One fifth of the films belonged to the genre of psychological films. The rule I used for this genre was that the time travel must take place in the mind of the time traveller, rather than their body being transported through spacetime. When the time traveller returns to their present, they must have a memory of how their present used to be before they started their journey.

The following types of time travel were used in these films:

- Head injury (5)
- Angels (4)
- Waking up in another time or place (3)
- Psychosis (3)
- Visions or dreams (2)
- Drug induced (1)
- Hypnosis (1)
- Mind power (1)

The last 20% of the films belonged to the genre of fantasy films. The rule I made here was that no scientific explanation (physics or psychology) is given about how the time

travel takes place. Some of the films made no attempt to explain how the time travel had happened while others went only as far as to say it involved magic. The following types of time travel were used in the fantasy films:

- Finding portals (9)
- Magic (5)
- Unexplained (4)
- Ancient artefact (2)

Past-future rules

The next observation I made about the films was that time was not always treated in the same way. In some films time was open, meaning that events could be changed, which meant that the future was not predetermined, whereas in other films time was closed, which meant that all events were fixed in time and that the future was therefore predetermined.[1] After further analysis of the films, it became clear that there were different rules about whether the past or future was open or closed. Therefore, one of four different mutually exclusive rules were being applied to each film:

- Open past, open future
- Open past, closed future
- Closed past, open future
- Closed past, closed future

The open past, open future rule

With an open past rule, a time traveller who goes back in time can change events, and these changes may or may not have an effect on the future. If the time traveller were to go into an open future, they would also be able to change anything they wanted. Again, these changes may have a permanent effect on the distant future or not. They would have to travel there before they had made any changes and then again afterwards to see if they had made a difference or not. Making changes to the past that cause the timeline to diverge away from the original could create the kind of temporal paradoxes discussed in the background chapter.

[1] This term 'closed', which I have defined to mean fixed, should not be confused with the term 'closed loop'.

A good example of a film with an open past, open future rule is *Back To The Future Part II* (1989). In this sequel, Doc Brown uses his time machine (a DeLorean car) to travel from 1985 to 2015, where he finds his friend Marty happily married to Jennifer, but their children are about to go to jail. So he comes back to 1985, collects Marty and Jennifer and takes them forward in time to 2015 to sort out the mess. Soon after they arrive, they are recognised by Biff, [Marty's enemy in the original film] who is now an old man. Biff steals their DeLorean car and travels back sixty years to 1955, where he hands his younger self a sports almanac containing all the sports statistics until the end of the century. He then returns the car to his own time before Marty and Doc notice it is missing. By winning millions on gambling, Young Biff distorts the past creating a new timeline, which then turns their hometown in 1985 into a living hell. When Doc and Marty return there, they soon realise what has happened and go back to 1955 and prevent Old Biff giving the almanac to Young Biff, which restores the original timeline. The future and the past are changed with consequences in this film, so it can be deduced that both the past and future are open.

The open past, closed future rule

The consequence of this rule is that there is a fixed destiny that we each have, as does the world. Although a time traveller can leave the present and venture back to change the past, no matter what they change, nothing will affect destiny from their moment of departure onwards. This allows for a self-consistent universe without temporal paradoxes.

A good example of a film with an open past and a closed future is *Groundhog Day* (1993): Phil Connors spends Groundhog Day filming a weather report on location with his crew. At 6 am the following morning, he is woken by his alarm clock in his Bed and Breakfast accommodation, and discovers that Groundhog Day is repeating itself all over again. This happens every morning, and he gains cumulative memories, so he is able to learn from his mistakes and watch his days get better each time. At one point, he realises that he is doomed to spend the rest of his life trapped in Groundhog Day, so he tries to escape by committing suicide, but that does not work because he still wakes up at 6 am the following morning and it is still Groundhog Day. The same external events keep happening day after day, but Phil is able to change the way he reacts to them and make different decisions about the way he is going to behave. Phil is the only one who can remember that time has gone back. This continues until one day he makes a change

that moves him out of the time loop. The following morning, he wakes up to find that he has progressed to the next day, so that he has escaped Groundhog Day.

Note that although this is a time loop, it is not a causal loop because the actions he goes back and makes in the past do not cause his present situation to take shape. The past is open because Phil changes his interactions with people each time that he goes back when re-experiencing the same day. After the final trip around the time loop, he wakes up to find himself finally experiencing the next day. The future must be closed in this model of time, as only one future was possible. So in this film, the past is open and the future closed.

The closed past, open future rule

With this rule, a time traveller who ventures back to the past is unable to change anything. Either they can observe the past in a non-interacting manner, or they can relive moments of their past without being able to change them. However, the future has not yet happened and only probable futures exist. After travelling forwards in time to observe a probable future, it is possible to return to the present and make different decisions that would cause a different future to be realised.

A good example of a film with a closed past and an open future is *Click* (2006). Michael goes shopping for a universal remote at a department store and meets a salesman called Morty, who gives him one for free. When he gets home, he finds he can use it to go backwards or forwards in time viewing his life. Morty shows up from time to time and explains that he cannot go back and change anything; he can only rewind to scenes of his life in which he was present and view them, like watching a film of his life on DVD. He and Marty are never noticed as they walk around the scenes of his life. He fast-forwards to various parts of his life and eventually finds that he has become very successful, but his wife and kids have left him and she is now remarried. He is rich, successful and very overweight. He sees how of much of his family life he missed and how his life will get much worse unless something changes. So he starts to make his family a priority, thus creating a different future for all of them. Therefore, in this film the past is closed and the future is open.

Another good example would be any one of the more than twenty film adaptations made of Charles Dickens' novel, *A Christmas Carol* (1843).

The closed past, closed future rule

With this rule nothing can be changed in the past or the future, not even the smallest detail. A time traveller can appear to be changing the past when they go back, but anything they do will only cause the original chain of events to unfold in exactly the same way.

A good example of a film with a closed past, closed future rule is *Slaughterhouse Five* (1972). Billy jumps in and out of time experiencing different parts of his life over and over again, but every part always plays out exactly the same. When he leans back to rest, he often drifts into a trance, and finds himself experiencing another random period of his life. We see him reliving different parts of his life, including when he is shot dead as an old man. At one point, some aliens abduct him and take him to their planet, Tralfamadore, where time and free will do not exist. The Tralfamadorians can see him, but he cannot see them, as he is told that they live in another dimension. He asks when he can leave and is told, "You are here, you have always been here and you will always be here… We have visited 31 inhabited planets in the universe, we have studied reports on a hundred more, and only on Earth is there any talk of free will!" Back on Earth, he is on stage giving a talk about Tralfamadore and when he tells the audience that he is about to be shot, they gasp. He tells them, "If you protest, if you think death is a terrible thing, then you've not understood what I've said … it's time for me to be dead for a little while." A member of the audience, who had threatened to one day kill Billy when they were in the same prisoner of war camp, pulls out a gun and shoots him dead. The film ends on the timeless planet with Billy with his new girlfriend, Montana, holding their newborn son.

In this film, Billy makes random jumps back and forwards through his life, but as he cannot change anything, both the past and future are closed.

The undefined past

After further analysis, it became apparent that some of the films only deal with time travel to the future, and therefore it is not possible to say whether they had an open or closed past. In such cases it can only be stated whether or not the future was open or closed. Therefore, the 'Undefined Past' is not a fifth rule as such, but rather a way of categorising a film that does not contain enough information to describe whether the past is open or closed.

A good example of a film with an undefined past and open future is *Planet of the Apes* (1968). Captain Taylor is on an American spaceship that left Cape Kennedy six months before. The dashboard shows the year on Earth to be 2763 A.D. According to the theory of a scientist called Dr Hesline, the earth would have aged nearly 700 years since they left, as their ship has been travelling at nearly the speed of light. All of the crew go into a deep sleep for the remaining 12 months of their journey and awake to find their ship crashed on an unknown planet with a similar climate to Earth. The dashboard now shows the Earth's year to be 3978 AD, so it seems they have jumped forward another 1,215 years. The crew estimate that they are "320 light years from Earth, on an unnamed planet in orbit around a star in the constellation of Orion" and they soon find they are on a planet dominated by apes with human slaves who are savage mutes. Taylor eventually realises that they are back on Earth, but in a distant future where a nuclear explosion had caused the fall of human civilisation, and had allowed the apes to take control of the planet.

The theory of Dr Hesline obviously refers to time dilation in Einstein's Special Theory of Relativity. Travelling in an extremely fast vessel through space will cause time to slow down on the vessel relative to Earth. Time will seem to be passing normally to both the crew of the ship and to the inhabitants of Earth, but when they meet again, their clocks will be unsynchronised. In this case they are 1215 years apart. The past was not changed in this film because nobody went back in time, but we cannot assume that the past is fixed because there is not enough information to make that conclusion. However, the future is changed by their arrival compared to how it would have been if the time travel journey had not taken place. So in this film, the past is undefined and the future is open.[1]

Guyline graphs

In order to help analyse the reviewed film, a graphical technique was developed to represent how the timeline was being changed (or not) by each character in the film. A 'timeline' is a line that represents a series of events in time, as shown by the orange line in Figure 25. Note that this graphical representation of time assumes linear time, which is the type of time most prevalent in our western society, from which the vast majority of the films that I reviewed came.

[1] However, if the time travel journey was predestined, it could be said that the whole timeline was fixed and not open, but there is not enough evidence to support this scenario.

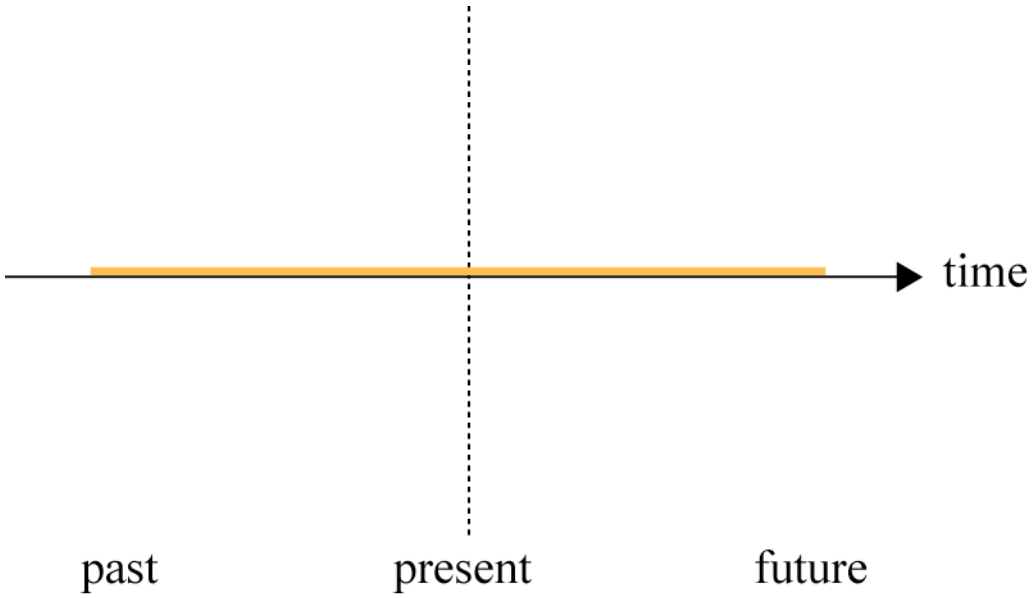


Figure 25: A guyline graph with a timeline that represents a series of events in time

The orange timeline in Figure 25 could for example represent world events from one hundred years ago through to one hundred years into the future. If a time traveller left the present moment and reappeared on the timeline 75 years before, the blue line in Figure 26 would represent their journey through time.

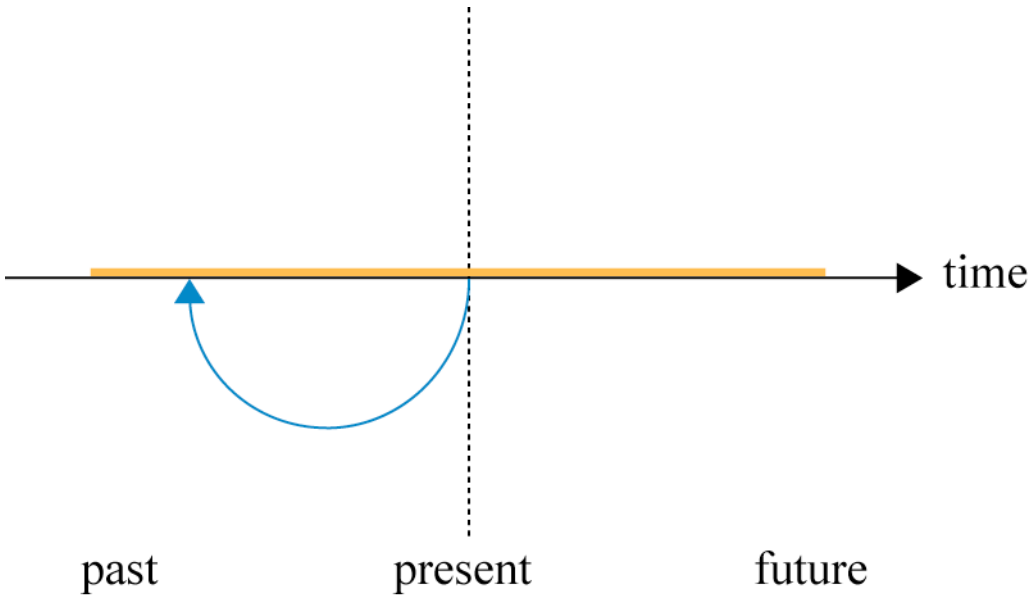


Figure 26: A guyline graph shows a time traveller making a trip back in time

The time travel journey in Figure 26 does not take any time. The blue line represents a movement from the origin to the arrival point. It would be as if the axis had been temporarily bent around so that the point of departure at the origin and the point of

arrival were touching, so that the time traveller could move into the past in an instant. The blue arrow shows the direction of travel. The blue line can also be used to show how an object or just information is transmitted from one point on the timeline to another.

Every guyline graph in this thesis has the start point of the first time travel journey placed at the origin of the graph. Therefore, everything that happens after this point in time is considered to be in the future, and everything that happens before this point is considered to be in the past.

A guyline graph graphically represents a time travel journey or journeys that a film character made, and shows how the events in time have changed (or not). Each character within a film has a unique guyline graph that represents their journey(s) unless they made the same trip at the same time as another character, in which case their guyline graphs would be identical. However, the model of time for each film is universally applied to each character and to each journey. Therefore, a film can only have one model of time, although it can have multiple guyline graphs, which each represent a different character's journey(s). From the point when the time traveller arrives on the timeline, the events may or may not change due to their presence. Figure 27 shows an example of how a new (green) timeline could replace the original (orange) timeline from that point onwards.

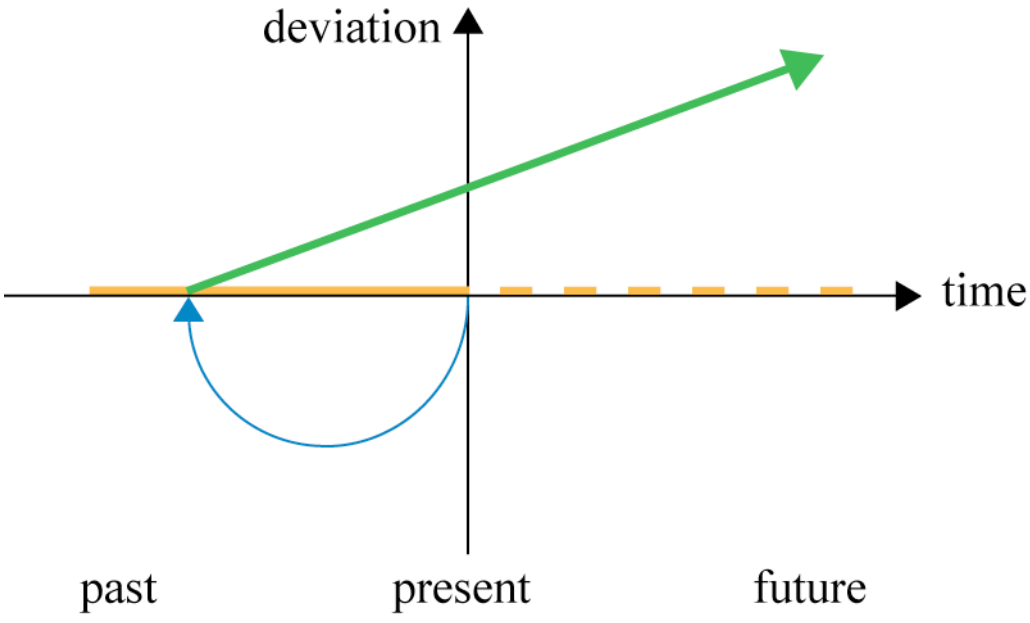


Figure 27: A guyline graph showing the time traveller's journey and the resulting change to the timeline

The y-axis represents how far the events of the green timeline deviate from the original events of the orange timeline. Note that the orange timeline is now dashed from the origin onwards as this future is now only a potential future that will not take place unless other changes take place. However, the events before the origin on the orange timeline have already taken place, so it remains solid.

Once on the new timeline, if the time traveller chose to return to their present, then they would continue along the new timeline as shown in Figure 28. Depending on how much the timeline had diverged from the original, they may find their present to be a very different place from the one they left behind.

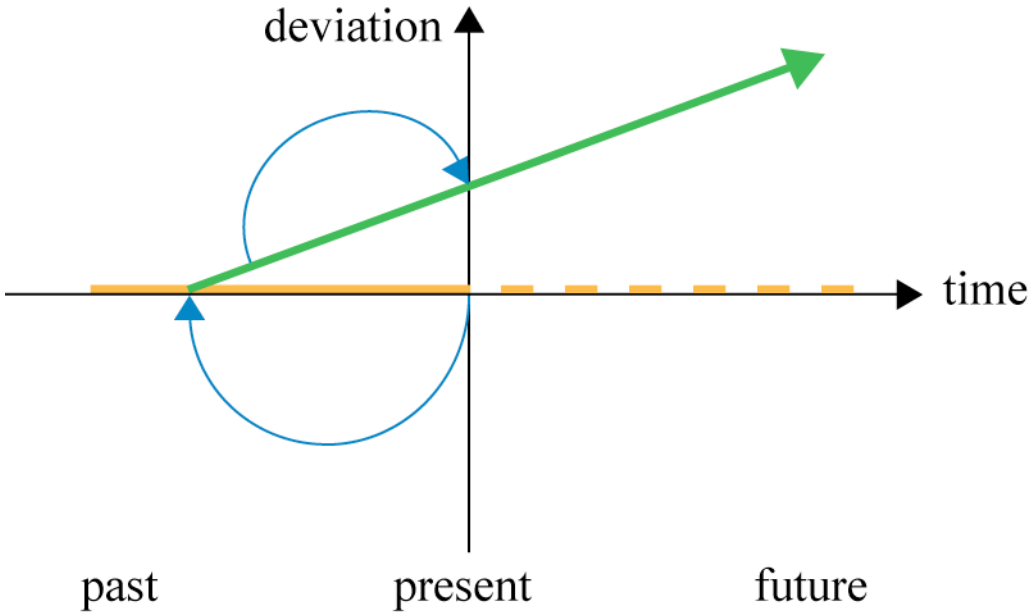


Figure 28: A guyline graph showing forwards time travel along the new timeline

To recapitulate: the time traveller moves along the original (orange) timeline until the graph's point of origin. At that point they travel back in time and appear in the past. Their arrival then causes a new (green) timeline to be created, which replaces the original timeline. They now travel along the new timeline whose events are starting to deviate away from the original events. They then travel forwards to the year that they started their journey, but find that history has changed since they began their journey.

A more complex example would be the *Back To The Future* trilogy because it has time travel trips to the future as well as return trips to the past. A guyline graph for Marty,

the protagonist, is shown in Figure 29.[1] The date his first time travel journey began was 1985, so this date has been placed at the origin of the graph. Everything before this date is therefore his past and everything forward of this date is his future. The blue lines represent Marty's different time travel journeys.

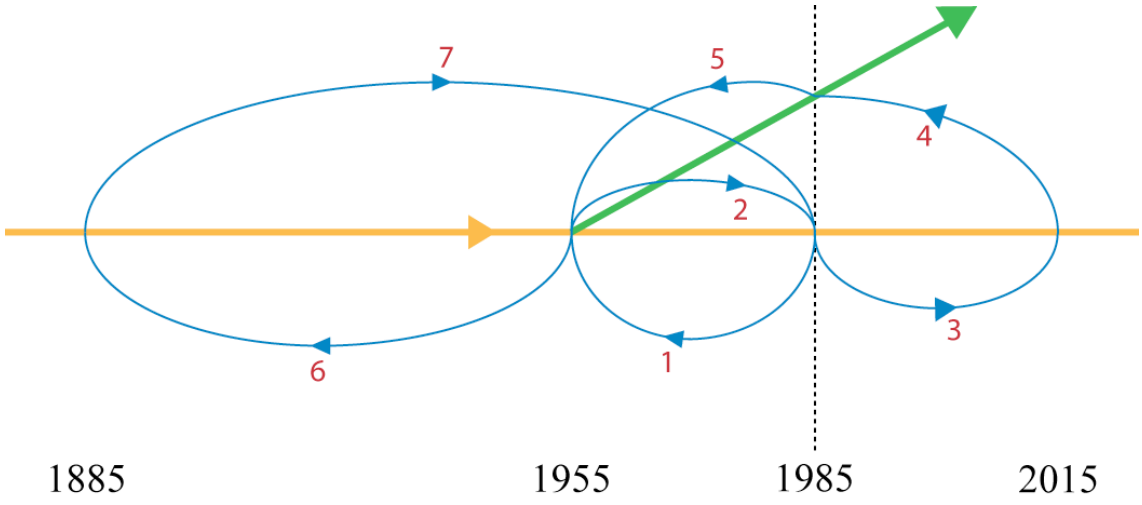


Figure 29: A guyline graph of Marty's time travel in the *Back to the Future* trilogy and the resulting change to the timeline

The red number next to each blue line shows the order in which each trip took place. Each trip is described as follows:

1. Marty starts his journey in 1985 as he takes a trip back to 1955.

2. He meets a younger version of Doc Brown, who helps him get the time machine working again, so Marty returns to 1985.

3. At the start of the second film Doc Brown has just come back from the future; he collects Marty and takes him there.

4. While they are in 2015, Biff steals their time machine and travels back to 1955, where he gives his younger self a sports almanac. Biff then returns to 2015 and replaces the time machine before anyone notices it has been taken. Young Biff starts to bet on the sports results in the almanac, which eventually causes events to diverge away from the events on the original timeline (orange) and along the

[1] The full version of this guyline graph is even more complex. This version has been simplified for the purpose of explaining how timelines work.

new timeline (green) instead. Doc and Marty get into the machine and return to 1985.

5. However, when they get there, everything has changed because the orange timeline has been replaced by the green timeline. They then decided they have to travel back to the point of divergence in 1955 and steal the almanac from Young Biff, so that the timeline will no longer diverge.

6. As they prepare to return to 1985, an accident with lightning causes Doc Brown to travel back 100 years in the time machine, leaving Marty stranded. Doc hides the time machine in a cave and leaves a message for Marty, so that he can find where it is hidden in 1955. At the start of the third film Marty receives the message and retrieves the machine from the cave, but discovers in a history book that Doc was shot and killed in a dispute. So instead of returning to 1985, he travels back to 1885 and saves Doc's life.

7. However, Marty cannot convince Doc to return to 1985 with him because Doc has fallen in love, so Marty has to return to 1985 alone.

On his return, Marty allows the time machine to be destroyed, thus ensuring that no more time travel journeys can be made, and the timeline can remain stable.

Doc Brown's movement along the timeline is not the same. Figure 30 shows how the timeline itself has not changed, but the blue lines, which represent the Doc's time travel journeys are different from the ones on Marty's guyline graph.

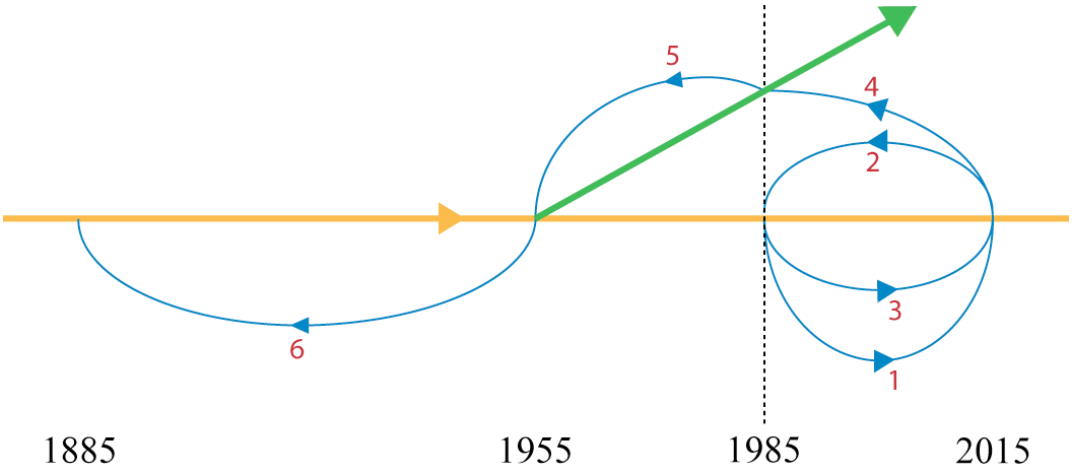


Figure 30: A guyline graph of Doc Brown's time travel in the *Back to the Future* trilogy and the resulting change to the timeline

Biff's movement along the timeline is shown in Figure 31. Notice how the present date for him is different because he started his original time travel journey in 2015 and never travelled into his future, as he only made one return trip to his past. Biff went back in time and changed the past by giving the sports almanac to his younger self, who did nothing with it for a while, as shown by the converging green line. Biff returned to his present, which had not changed at this point, as the green timeline was still continuing to converge.

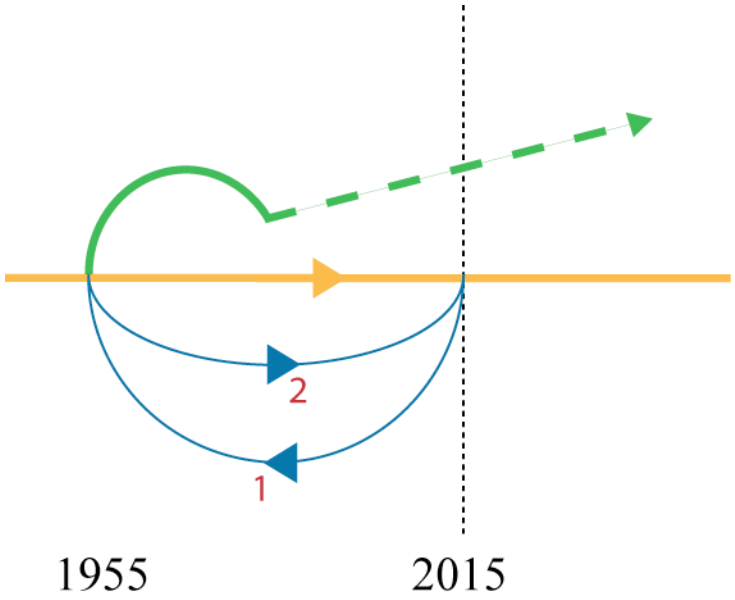


Figure 31: A guyline graph of Biff's time travel in the *Back to the Future* trilogy and the resulting change to the timeline

The dashed green timeline shows the potential for the timeline to diverge. At first, Young Biff did not take any action by betting on the results in the almanac, but once he did, it changed the future of the whole town. This caused the green dashed diverging timeline to become a reality rather than a potential and it therefore became a solid green line. This also caused the orange line to become dashed in the future section of the graph because that future had become only a potential. This of course created a paradox because the timeline from which Old Biff came only existed as a potential timeline when this happened. If parallel worlds existed, both the green and orange lines would remain solid, but that was not the case in this film.

Note that the converging timeline is not to scale in the above diagram. The timeline only converged for a few days while Biff thought about whether to use the almanac or not, then once he did, it severely diverged. Therefore, if the start of the green diverging

timelines in Figure 29 and Figure 30 were magnified, they would show a small convergence before they diverged away.

Types of timeline

My initial observation about films was that there were two types of timeline:

1. A ‘diverging timeline’, where the original timeline is replaced by a new one containing altered events. It diverges away from the original one causing a different future.
2. A ‘parallel timeline’, where the new timeline sits in parallel to the original one, so that two alternate futures with different outcomes can exist at the same time.

After further analysis of the films, a third and fourth type of timeline were discovered:

3. A ‘converging timeline’, where the original timeline is replaced by a new one containing altered events. It starts to diverge away from the original one, but then converges back so that the long-term future remains unchanged.
4. A ‘double well timeline’, where the original timeline is replaced by a new one containing altered events. It starts to diverge away from the original one, but then converges back towards it. However, a change at just the right time and place can cause the timeline to permanently diverge off causing a very different future.

These four timelines were then joined by a fifth one:

5. A ‘fixed timeline’, where the original timeline cannot be changed or replaced. It is synonymous with the closed past, closed future rule because the timeline cannot diverge from its original path.

These five timelines are each explained in more detail with examples of films that used them.

Diverging timeline

On this type of timeline, when a time traveller arrives further back in time, the original timeline collapses or disappears and is replaced by a new one that contains the time traveller.

A good example of a film with a diverging timeline is *Terminator 2: Judgement Day* (1991). John Connor captures a Terminator robot, reprograms it and sends it back through time on a mission to protect his younger self. Another cybernetic organism soon follows, a T-1000 advanced prototype, whose mission is to kill the young John. The first Terminator helps John to escape from the T-1000. Meanwhile, John's mother, Sarah is having recurring dreams, where she meets her dead lover, Kyle, who tells her that John is in danger and reminds her of his message from before, "The future is not set, there is no fate, but what we make for ourselves." The terminator tells them that a man called Dyson was the creator of 'Skynet'. They think that if they can stop him, they can stop 'Judgment Day': the day when Skynet launches the nuclear missiles that destroy most of the human population. They find Dyson and with his help, go to the factory that was going to create the self-aware machines. On the way to the factory, Sarah narrates the following, "The future, so clear to me, had become like a black highway at night. We were in unchartered territory now, making up history as we went along." They destroy the factory and the remains of the first Terminator, which was kept there. The surviving Terminator allows them to terminate him to remove all evidence that might allow that possible future to be regenerated. So in this film, a new timeline that permanently diverges off to a new future replaces the previous one as shown in Figure 32.

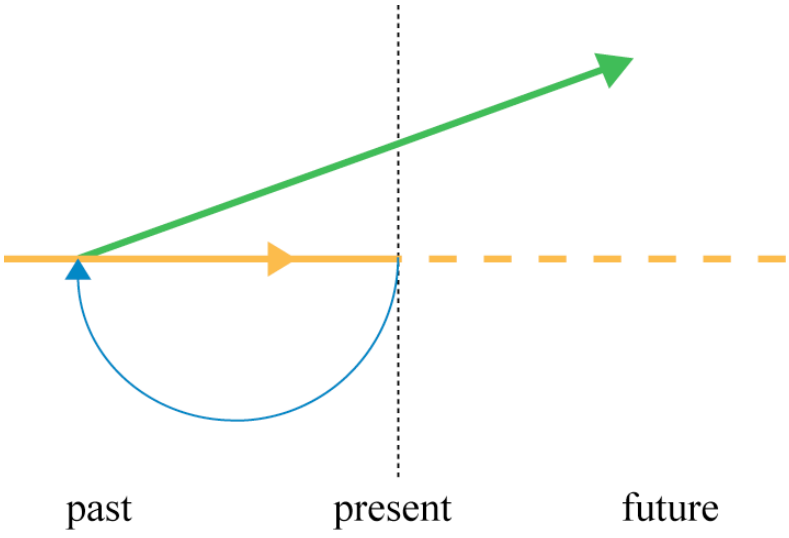


Figure 32: A guyline graph showing the Terminator's time travel in *Terminator 2: Judgement Day* (1991) and the resulting change to the timeline

A guyline graph showing the second Terminator's time travel would be identical. The model of time used in this film was a diverging timeline with an open past and open future.

Rather than using a time machine to transport a body back through time, it can also be possible to cause the timeline to diverge by sending only the time traveller's consciousness back in time, so that it comes to rest inside the mind of their younger self. With foresight they would then be able to make different decisions, which might cause the timeline to diverge to a different future. They would then have to travel forward to discover if the changes had made a permanent difference.

A good example of a film with this type of diverging timeline is *The Butterfly Effect* (2004). Evan is a young boy, who suffers from memory blackouts when experiencing traumatic events. His therapist asks him to keep a diary of these moments, so he can remember what happens. When he is a young adult, he starts to read one of his old diaries, falls into a trance and begins to re-experience the event with his adult point of view. He tries to change the past for the better and when he comes out of the trance, this small but significant change in his past has had enormous consequences for his present.

Evan's father had the same ability, but was committed to a mental home. He tries to warn Evan that the more attempts he makes to fix the mistakes of his past, the more problems that are created in the present. It seems this genetic defect is passed down from father to son. At the end of the film, to prevent himself from also going mad, he goes back to the womb and strangles himself with the cord, before he can be born. His mother had had two stillbirths before him, so presumably these sons had gone back and also committed suicide in the same way. The story ends with the lives of his childhood friends turning out much better without him being born; his mother even gives birth to a baby, who cannot have the genetic defect because she is a girl.

Whenever Evan returns to his present, the timeline has strongly diverged to a very different future, so this film is also using a model of time with a diverging timeline as shown in Figure 33.

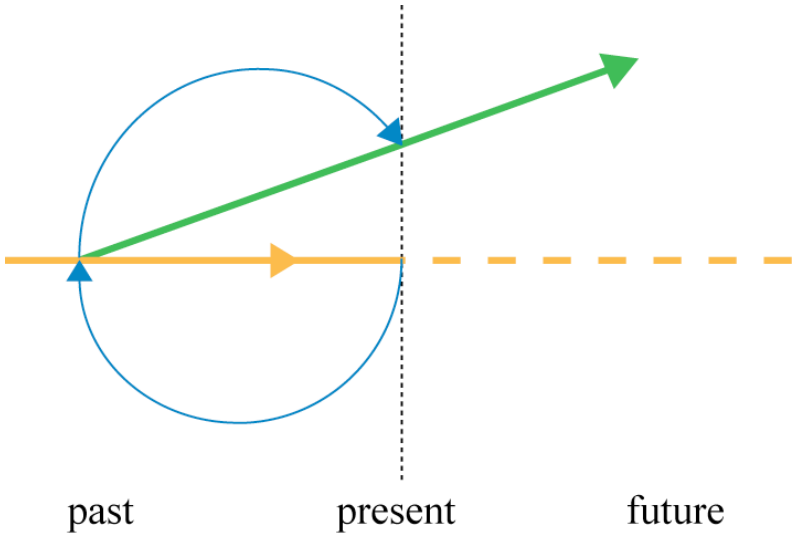


Figure 33: A guyline graph showing Evan's return time travel in *The Butterfly Effect* (2004) and the resulting change to the timeline

Each subsequent trip that Evan took would have an identical guyline graph. The model of time used in this film was a diverging timeline with an open past and open future.

Another difference between *Terminator 2: Judgement Day* and *The Butterfly Effect* is that the former, unlike the latter, has no time travel forward to the present to find out if the timeline really had permanently diverged to create a new future. However, both films are considered to have a diverging timeline, as this is what the characters believed was happening and what the director wanted the audience to think was happening.

Parallel timeline

When a time traveller arrives at a new point on this type of timeline, from that point onwards, a new timeline that contains the time traveller is created in parallel to the original timeline, which remains undisturbed. Therefore, the time traveller cannot appear on the original and history is not changed at all on it. After the split, the new timeline could continue alongside the original, or keep diverging forever, or it could start to diverge and then converge back again. However, the important difference here is that unlike the above three timelines, the original timeline remains in parallel undisturbed by the time traveller.

A good example of a film with a parallel timeline is *Sliding Doors* (1998). Helen Quilley is dismissed from her job, so leaves work earlier than usual. At the train station, as she is running down the stairs to the platform, she bumps into a girl with a doll,

which delays her by only a couple of seconds. Just before she gets to her train, the sliding doors close, causing her to have to wait for the next one. Then, without explanation, time rewinds and we see Helen running down the stairs again. However, this time the girl with the doll is pulled out of the way by her mother, which means that Helen gets to the sliding doors of the train just in time to board. The story then continues with two parallel timelines: in one timeline she leaves her cheating boyfriend, and ends up in a loving relationship with James, the man she met on the train. In the other, she returns home later, so does not find out that her boyfriend has another lover until near the end of the film. She experiences some parallel events: for example in both lives, she ends up in hospital after suffering a life-threatening injury while being pregnant. In one life Helen dies and James is distraught, while in the other she survives the accident, but the baby does not and she tells her boyfriend to leave her for good. On her way out of the hospital, the sliding doors of the elevator close just as she arrives. However, the person inside opens them again and she steps inside to meet James for the first time in this timeline. So in this film, a new timeline was created when she went back in time and the original timeline remained undisturbed in parallel to the new one, as shown in Figure 34:

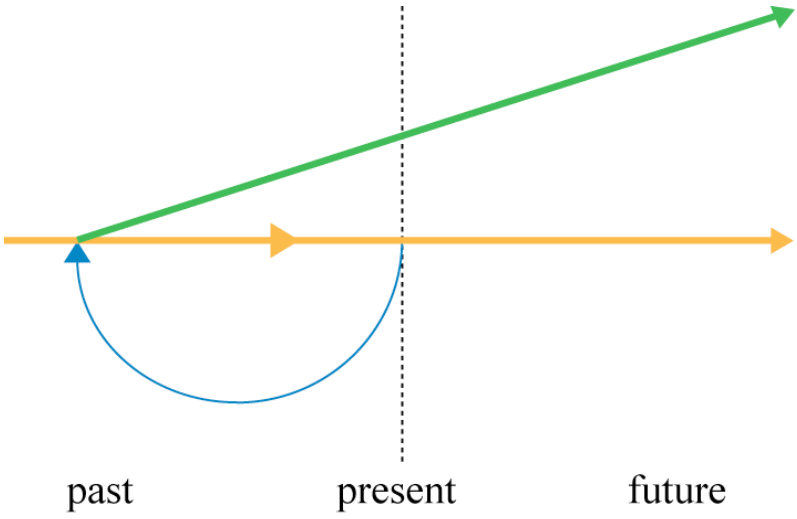


Figure 34: A guyline graph showing Helen's time travel in *Sliding Doors* (1998) and the resulting change to the timeline

The model of time used in this film was a parallel timeline with an open past and open future.

The main difference between the parallel timeline and the diverging timeline is that the original timeline is not replaced. This means that history is not changed on the original timeline, and therefore certain temporal paradoxes are avoided, which means that the events along the timeline can remain self-consistent. Note that the new timeline on the guyline graph may be diverging from the original, converging towards it, or anything in between; it does not have to be in parallel to the original line. 'Parallel' refers to the fact that the new events exist in a parallel world, not that they have all deviated an exact amount from the original events such that the new line runs parallel to the original.

Converging timeline

Like the diverging timeline, the converging timeline also replaces the original one and diverges away from it. However, at some point, it begins to converge back towards the events of the original timeline. As both of these timelines replace the original, they are types of a 'replacement timeline'. Because they return to where the original timeline was before the time travel began, this type of diverging timeline is able to maintain its self-consistency and avoid temporal paradoxes like the parallel timeline did.

A good example of a film with a converging timeline is *Terminator 3 - Rise of the Machines* (2003). This film begins with John Connor quoting his mother, Sarah, from the previous Terminator film, "The future has not been written. There is no fate but what we make for ourselves," and then he says, "I wish I could believe that." An extremely advanced terminator (TX) comes back from the future to kill the young people who will become John's lieutenants when he is leader of the human resistance. They, in turn, send back a re-programmed terminator, as before, to oppose it. John tells the terminator that it should not even exist, as he had stopped Judgment Day (the beginning of a war between man and machines), but the terminator tells him, "You only postponed it, Judgement Day is inevitable." They visit Sarah's coffin and find it full of arms that she left for John just in case the robots came back. John realises that she did not fully believe her conviction either. He finds out more about his future and how he will die, but then gives up the idea of a predestined future, and sets off in a plane with Kate to blow up the supercomputers that he believes control Skynet. He tells her, "We are going to make it Kate - the future is up to us." At the end of the film, after John has failed in his mission to destroy Skynet, a voiceover from him explains, "I should have realised our destiny was never to stop Judgement Day - it was merely to survive it

together. The Terminator knew, he tried to tell us, but I didn't want to hear it. Maybe the future has been written, I don't know."

Although the timeline diverges when the robots arrive from the future, the humans eventually realise that they are powerless to prevent it from converging back to the point where the machines take over and create the terminator robots. Judgement Day can be delayed for the timeline to remain self-consistent, so long as the timeline converges back by the time the first terminator was sent back through time, as shown in Figure 35.

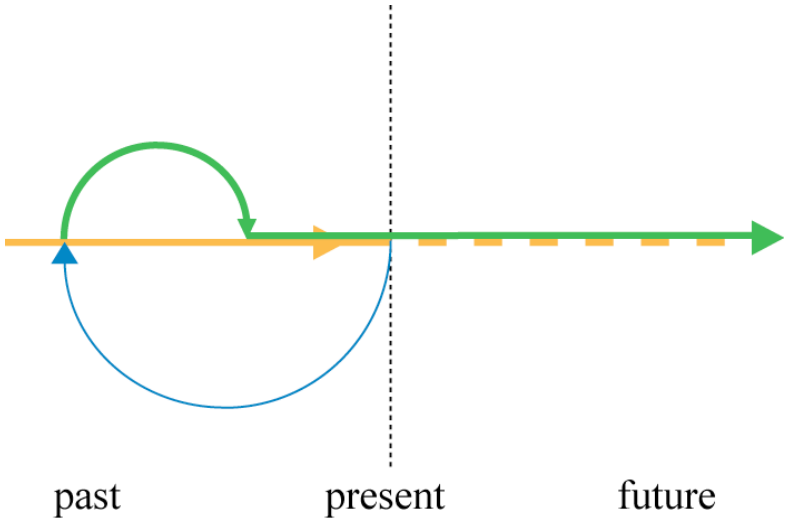


Figure 35: A guyline graph showing the Terminator's time travel in *Terminator 3 - Rise of the Machines* (2003) and the resulting change to the timeline

A guyline graph showing the second Terminator's time travel would be identical. The model of time used in this film is a converging timeline with an open past and closed future. It is an example of the application of Novikov's self-consistency conjecture.[1]

Double well timeline

In mechanics a 'double well' model can be used to demonstrate the potential and kinetic energy of a ball. One of the wells contains a ball, which can be set into simple harmonic motion as shown in Figure 36. The ball will not move into the adjacent well unless it is given sufficient energy to change its velocity at just the right time and place. If the system is damped, the ball will eventually come to rest at the bottom of one of the

[1] Previously discussed in the section, 'Novikov's self-consistency conjecture' on page 64 of Chapter Three.

wells. The next timeline, which I have named the 'double well timeline', is also a replacement timeline as it combines elements of both the diverging and converging timelines, but unlike them, it can accommodate causal loops.[1]

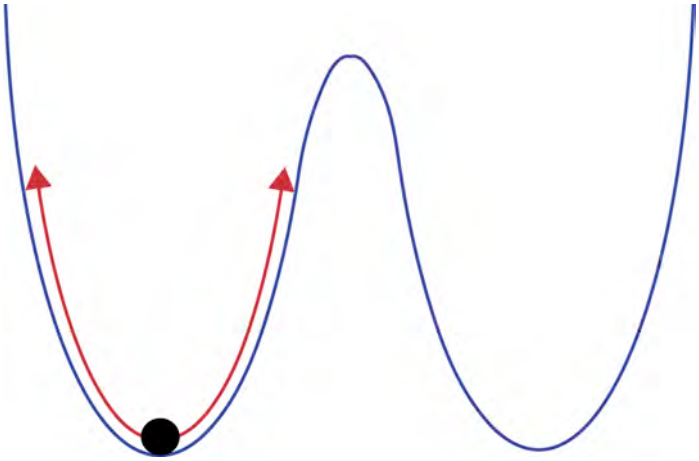


Figure 36: A ball moving with simple harmonic motion in a double well

It is similar to the double well model in mechanics in that it will converge back to the original timeline (stay in the same well) unless a significant enough change is made at just the right time and place. This causes the timeline to diverge off to a different future (an adjacent well).

An example of a double well timeline is when a time traveller arrives in the past and notices that their presence has caused the timeline to diverge away from the original timeline. However, after a while, they realise that the timeline is converging back towards the original future. Maybe they even spot that the very things they are doing to try and change the timeline are causing events to happen in just the way that history told it. In other words, they are experiencing causal loops. The more they try to change the future, the more the timeline converges towards the same future as before. This process continues until they make a significant enough change at just the right time and place, which changes everything and permanently causes the timeline to diverge away from the original. So a double well timeline is one where a change at the right time and in the right place can cause the timeline to permanently diverge off to a very different future. The important thing to note is that not every change will cause a different outcome, only a change at the right time and place will be sufficient, and it does not necessarily need

[1] The physics behind a causal loop was previously explained in the section in the section, 'The Paradoxes of Backwards Time Travel', which begins on page 62 of Chapter Three.

to be a large change. This works in a similar way to the Butterfly Effect, as discussed in the Chapter Three of this thesis.

A good example of a film with a double well timeline is *Déjà Vu* (2006). A ferry is blown up in New Orleans harbour, and agent Doug Carlin is invited to join a newly formed FBI surveillance team to investigate the explosion. Doug uses the team's time machine to send a note back in time, which arrives on his work desk warning him about the terrorist Oerstadt, but Doug's partner Larry picks it up instead. The terrorist kills Larry when he goes to investigate him, which creates one of the many causal loops in this film, as Doug is now responsible for the death of his partner. Back in the present, the FBI arrest and charge Oerstadt, who says, "Anyone, who tries to stop [the explosion] from happening, causes it to happen!" Doug uses the time machine to send himself back to try and stop Oerstadt from blowing up the ferry. When he arrives in the past, he is able to freely change events, but the more he changes them, the more he realises that the timeline is converging back and that he is not going to stop the disaster. He notices that the changes he makes are creating events that he had witnessed before he made his trip. These causal loops are examples of the predestination paradox.[1] Doug keeps trying and does eventually prevent the disaster by killing the terrorist before the bomb explodes, which causes the timeline to diverge off towards a new future.

We can see that the changes that Doug made to the past to stop the explosion from happening were apparently causing it to happen, but it is not clear whether the explosion would have taken place if he hadn't gone back in time. However, I am going to conclude that Doug had to go back in time, which would suggest that there are causal loops in this film, which indicate that until the major divergence, a model of time travel with a fixed timeline was being used, rather than a series of convergences and divergences. As Doug is able to finally cause the timeline to permanently diverge, the only the model of time used in this film has to be a double well timeline with an open past and open future, as shown in Figure 37.

[1] The predestination paradox was previously explained in the section, 'The Paradoxes of Backwards Time Travel' on page 62 of Chapter Three.

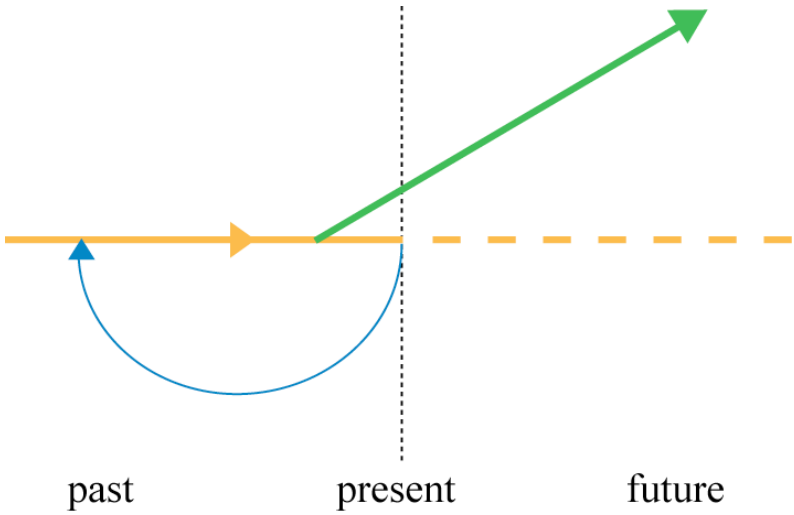


Figure 37: A guyline graph showing Doug's time travel in *Déjà Vu* (2006) and the resulting change to the timeline

A different kind of double well timeline was used in *Back to the Future* (1985). Marty travels back 30 years in time to when his parents are about to get together, and his presence causes his mother to fall in love with him, instead of his father. Before he returns to the present, he has to correct the distorted events of the past by getting his parents back together; otherwise he may cease to exist. So, the moment Marty arrives a new timeline is created, which from that point on replaces the old one, which collapses and ceases to exist. He notices that his presence is causing the new timeline to diverge away from the original one, so he spends the whole film trying to get it to converge back to the original timeline in order to avoid the grandfather paradox.[1] Because he achieves this, we never find out if he would have caused a different future to be created into which he was not born. As Marty and Doc Brown believe the timeline will converge back to the original if they do not make a significant change, they are careful not to make any. When Marty returns home nothing has changed, which means the timeline must have converged back. Therefore it could be said that this film is using a model of time with a converging timeline. However, this is not the case because Marty made decisions based on the fact that if he was not careful, the timeline may have diverged for good, as shown in Figure 38. Therefore this film used a double well timeline because the characters believed the timeline could diverge, and the director wanted the audience to believe this too.

[1] The grandfather paradox was previously explained in the section, 'The Paradoxes of Backwards Time Travel' on page 62 of Chapter Three.

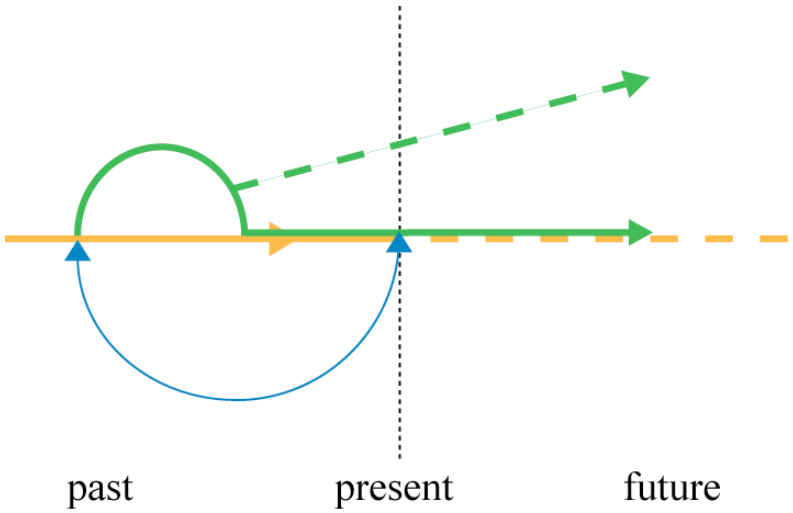


Figure 38: A guyline graph showing Marty's time travel back and forth in *Back to the Future* (1985) and the resulting change to the timeline

The model of time used in this film was a double well timeline with an open past and open future.

The difference between these two films is that in the first one, Doug's presence causes history to be written in exactly the same way as it was recorded, but in the second one, Marty's presence starts to create a different history. Doug is trying to change the present he came from, whereas Marty is trying to preserve it. The model of time in both films still has a double well timeline, even if the outcomes are different. Doug continues to make changes until he makes one significant enough to cause the timeline to permanently diverge. Marty knows that if he was to make a significant enough change, he too could cause the timeline to permanently diverge, so is very careful not to let this happen. Therefore a double well timeline could have an unchanged future, or a significantly different one depending on the timing and extent of the change made to the timeline, as explained in the butterfly effect.[1]

Any of these four timelines described can be combined with the previously mentioned past-future rules to produce different models of time. However, a timeline that has a closed past and closed future can never be changed, so it can only ever have one timeline: one that is fixed in time.

[1] See the section, 'Chaos Theory and Time Travel' on page 77 of Chapter Three.

Fixed timeline

This timeline is synonymous with the rule that has a closed past and a closed future because the timeline cannot diverge from its original path. In this model of time, a time traveller cannot change the past or the future because all events are predestined.

An example of a film with a fixed timeline is *Slaughterhouse Five* (1972), which has been previously discussed in this chapter. A different type of film that has a fixed timeline is one that has one or more causal loops, which can create either a predestination paradox or an ontological paradox, as discussed in the background chapter. As the time travel is predestined, this type of film also has a fixed timeline.

Twelve Monkeys (1995) is a film with causal loops and a fixed timeline: In the year 2035, only 1% of the world's population remains due to a terrorist, who has released a lethal virus at a string of cities around the world. Using a time machine, scientists send a series of convicts back to 1996, just before the virus was released. They are not hoping to change the past, only to gain a sample of the virus in its pure form before it has mutated, so they can control it better in their world. They choose convicts with strong visual memories, who will be able to retain detailed information about their trip. James Cole is chosen because of strong recurring images he has had since childhood of a running man being shot by a security guard at an airport. His mission is to locate 'The Twelve Monkeys', a radical group who they believe possess the virus. In 1996 he can leave messages for the scientists in the future by telephoning a number, which has an answer phone, so they can listen to the message in the future. When James discovers that The Twelve Monkeys are a harmless group of animal rights activists, his girlfriend, Kathryn, rings the answer phone and leaves an ironic message about the 'dangerous' Twelve Monkeys as a joke. This creates a causal loop because this message is why James was originally sent back in time. James then finds and chases the terrorist with the virus through an airport terminal. A small boy with his parents looks on in disbelief, as a security guard shoots James dead. Kathryn looks up and realises that the small boy is James as a child, who is witnessing his own death as an adult. This creates another causal loop because it was this event that caused his strong recurring images, which is why he was chosen to time travel in the first place.

Each time James returns from the past, nothing has changed in his world, which suggests that the model of time used here has a converging timeline. James said that he could not change his past, as it had already happened. So perhaps parallel worlds exist,

but in this case, it would make no difference to the scientists' timeline whether the terrorist was stopped or not, as it would only affect the new timeline. A change could only be made to the future of their timeline by bringing the virus back in its pure form. Due to several causal loops that exist in the plot, the timeline in this film has to be fixed because although it looks as if the past is being changed, in effect, every change that happens is causing the pre-existing future to occur.

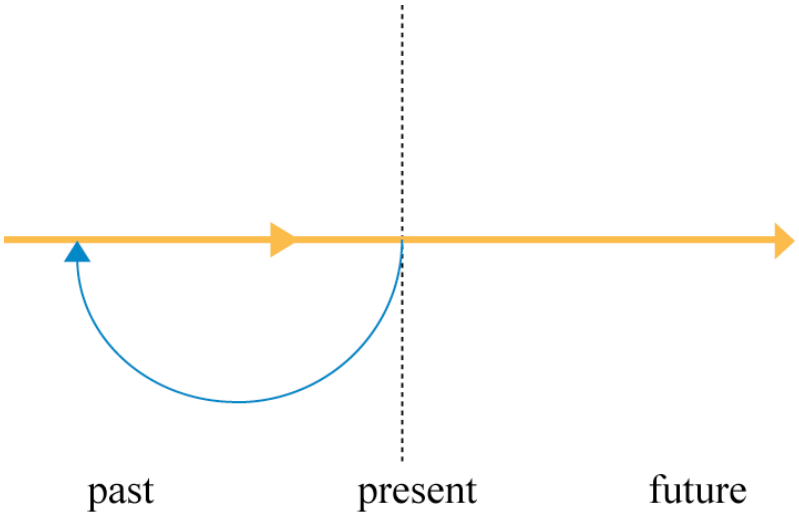


Figure 39: A guyline graph showing James's first time travel in *Twelve Monkeys* (1995) and the resulting lack of change to the timeline

A guyline graph showing Billy's first time travel in *Slaughterhouse Five* (1972) would be identical. Any subsequent trips either backwards of forwards would leave the fixed timeline unchanged. The model of time used in both these films was a fixed timeline with a closed past and closed future. Another difference between these films is that a human body is physically transported through spacetime in *Twelve Monkeys* (1995), whereas *Slaughterhouse Five* (1972) uses a form of mental time travel.[1]

Future timeline

This is not a type of timeline as such; it is just a way of classifying a film that does not contain enough information about the timeline to say if or how the timeline diverges because there is no information coming back though time. In a film that features time travel in the forward direction only, the past is not changed because no backwards time travel has taken place. Therefore, we cannot deduce whether the past is changeable or not; all we can say is that the past is 'undefined'. When the time traveller 'disappears'

[1] Types of mental time travel were previously discussed on page 68 of Chapter Three.

from the timeline at the start of their journey, this could cause it to diverge away from how it would have been had they stayed. However, this is not possible to know, unless at the end of his trip the time traveller were to come back to the point in time when they left and then make a comparison. So, we are left with an undefined future from the point the time traveller leaves to the point they reappear on the timeline, and an undefined past. As the time traveller has nothing to compare the timeline with, all they can say is that they are on a timeline, further into the future than when they left. Their arrival in the future may or may not affect the timeline, but again, if we have nothing to compare it to, we cannot say if their arrival there has made a difference. Without some information coming back from the future, it is impossible to make any comparison and therefore to know what difference, if any, the journey has made.

A good example of a future timeline is *Austin Powers: International Man of Mystery* (1997). This spoof of a Bond film is set in the 60s, with Austin Powers as the world's coolest photographer and part-time British secret agent. His nemesis Dr Evil cryogenically freezes himself so that 30 years later his body can be thawed, thus enabling him to come back to life as an unknown criminal. He plans to steal a nuclear weapon when he arrives and hold the world hostage for 100 billion dollars. Austin chases him through time by also freezing himself, so that he can stop him when he re-surfaces. They both arrive in 1977, and they have 30 years of missing information to be assimilated in order to acclimatise.

As with other films that involve cryogenic freezing and no backwards time travel, we cannot say if their departure from the timeline caused it to change or not, so we do not know whether the timeline they arrived on had converged or diverged since they left it. They cannot say if their arrival in the future made a difference because they have nothing with which to compare it. Therefore, the model of time used in this film was a future timeline with an undefined past and an undefined future as shown in Figure 40.

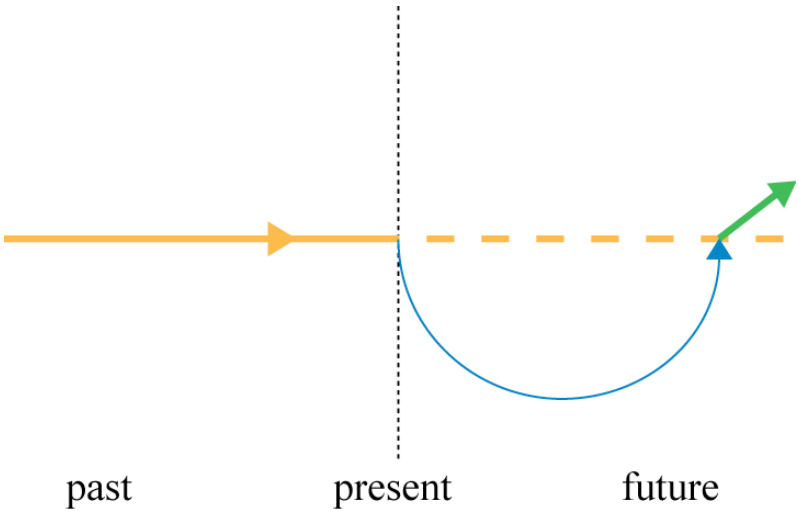


Figure 40: A guyline graph showing Austin's time travel in *Austin Powers: International Man of Mystery* (1997) and the resulting change to the timeline

This film is set in the sixties and the future for the characters is the seventies. It is interesting to note that because the audience is viewing the film from the nineties (or later), it knows what the seventies will hold, and whether the timeline converges or not. Therefore, we the audience do have information about the future time in which these characters arrive, but the important point is that the characters in the film do not, and that is what defines which model of time is being used.

Example of a full review of a film

Writing film reviews was not a trivial task, as they were often several pages long. However, it soon became apparent that I could cut down a film review to less than two pages and still adequately support my choice of which model of time was used. All 100 of these two-page film reviews can be read in Appendix I. An example of a full review of a film begins on the next page. *Donnie Darko* (2001) was chosen, as it was particularly hard to analyse.

Table 2 follows this film review, and it summarises the models of time used in each of the films that were reviewed in Appendix I. It shows which past-future rule was used in the film, which type of timeline was used and whether or not a causal loop was present.

Donnie Darko (2001)

Director: Richard Kelly

Writing Credits: Richard Kelly

Production Company: Pandora Cinema, Flower Films (II), Adam Fields Productions, Gaylord Films, Newmarket Films

Distributor: Pandora Cinema

Actors: Jake Gyllenhaal (Donnie Darko), Jena Malone (Gretchen Ross), Holmes Osborne (Eddie Darko), Mary McDonnell (Rose Darko), Maggie Gyllenhaal (Elizabeth Darko), Daveigh Chase (Samantha Darko), Drew Barrymore (Karen Pomeroy), Katharine Ross (Dr Lilian Thurman), Patrick Swayze (Jim Cunningham), James Duval (Frank)

Runtime: 133 minutes (director's cut)

Overview: A jet engine falls off a plane and passes through a time portal to 28 days earlier, which causes an unstable tangential universe to break away. Before the universe collapses upon itself, Donnie has to realign it by turning back time to before the event.

Plot Synopsis: On 2 October 1988 troubled teenager Donnie is sleeping in his bed at his family's New England home, when he begins to sleepwalk. He follows the voice he is hearing out of his house on to the golf course. It is the voice of a man in a Halloween rabbit costume, called Frank. He tells Donnie that the world will end in 28 days, 6 hours, 42 minutes and 12 seconds. At midnight, a detached jet engine falls through a time portal, which causes an unstable tangential universe to branch off from the primary universe. The next morning some passing golfers wake him, and when he arrives home, he finds that the jet engine has crashed through the roof of his house landing on his bed. No one can figure out where it came from because no airline is claiming responsibility. His family are relocated to a hotel and we hear the song, *Time Flies* by 'Tears for Fears'.

At school, Donnie's class is reviewing a book called *The Destructors* by Graham Greene. They discuss how destruction can be a form of creation. Following Frank's instructions, Donnie cuts the water pipes of his school with an axe, causing the whole place to flood, and then plants the axe in the head of a solid bronze statue. That is when we realise that Donnie has super-human strength when he is in this state. Frank tells Donnie, "I can do anything and so can you!" Donnie asks him where he comes from and Frank replies, "Do you believe in time travel?"

Later, Donnie's father, Eddie, is driving him, when they almost run over Roberta Sparrow aka 'Grandma Death'. She was crossing the road to check her mailbox like she does every day, but

never has any mail. They get out of the car to see how she is and she whispers into Donnie's ear, "Every living creature on Earth dies alone." With only 20 days to go, Donnie visits his science teacher to ask him if he knows anything about time travel. Dr Monnitoff explains to Donnie that a portal such as a "wormhole with an Einstein-Rosen bridge … may be able to provide a shortcut for jumping between two distant regions of spacetime". He gives Donnie a book to read by Roberta Sparrow called *The Philosophy of Time Travel*.

In a session with his psychologist, Dr Thurman, Donnie tells her that Frank wants him to go and talk to Roberta Sparrow. He says he does not want to die alone. That evening, Donnie is watching TV with his family, when he notices a spear of energy coming out of each person's solar plexus, forming a tube of energy, which appears to be pulling them towards wherever they are going next. Donnie notices his own and watches as it leads him upstairs to a wardrobe, where he finds a pistol. With 12 days to go, Dr Thurman tells Donnie's parents that he is experiencing "increased detachment from reality [with] daylight hallucinations … which are common for paranoid schizophrenics." She suggests more hypnotherapy and increased medication. When sleepwalking or in hypnosis, Donnie knows that he has been chosen to guide everyone home and realign the universe. However, this is hard to remember when he is conscious. His girlfriend, Gretchen, asks him, "What if you could go back in time and replace all those hours of darkness and replace them with something better." He shows her the book and says, "I've been seeing a lot of messed up stuff and there are chapters in that book that describe what I've been seeing. That can't just be a coincidence." The book explains that the tangent universe is highly unstable, so eventually it will collapse upon itself, causing a black hole to be formed within the primary universe that is capable of destroying all existence.

Later on Dr Monnitoff explains to Donnie, "Each vessel travels along a vector through spacetime along its centre of gravity … in order for the vessel to travel thought time, it has got to find a portal, in this case a wormhole." Donnie asks if these portals could appear anywhere at any time. The doctor replies that this is highly unlikely, he says, "I think what you are talking about is an act of God." Donnie replies, "Well if God controls time, then all time is pre-decided … every living thing follows a set path. If you could see your path or channel, then you see into the future, right? A form of time travel." The doctor says, "If we were able to see our destinies manifest themselves visually, then we would be given a choice to betray our chosen destinies. The mere fact that this exists would make all preformed destinies come to an end." Donnie retorts, " Not if you travel in God's channel!" Director, Richard Kelly, says that Donnie is trying to put together what he has seen in the book with what he has seen in life and then relate it all to religion in a search for God.

Donnie takes Gretchen to the movies and she falls asleep. Frank appears in his rabbit suit next to them and asks Donnie to watch the screen, where he distorts the movie to show Donnie a

time portal. Frank takes off the head of his rabbit costume to reveal his identity. We see that it is his sister's boyfriend, Frank. He has one eye missing which foreshadows that Donnie will shoot him through the eye later. Frank tells Donnie to burn a local celebrity's mansion to the ground. He does so and returns to the theatre before the end of the movie and before Gretchen wakes. In a session with Dr Thurman, under hypnosis Donnie confesses to her about his acts of vandalism. He explains, "I have to obey [Frank], he saved my life … I have the power to build a time machine … Time is up Frank says … Frank is going to kill … The sky is going to open up." She tells him that if this world were going to end, there would only be him and no one else. Donnie posts a letter to Roberta Sparrow.

Donnie's younger sister and friends are flying to LA the next morning to perform on TV. Their mother, Rose, has to escort the children there and his father will be away in New York for the weekend, so Donnie and his elder sister decide to hold a Halloween house party. Rose leaves a message on their home answer phone to say that she is catching the red-eye flight home and will arrive back at 8 am. At the party, Elizabeth is looking for her boyfriend, Frank. She is told he has gone on a beer run. With only six hours remaining, Donnie knows time is running out: the tangent universe is about to collapse and take the primary universe with it. He looks into one of these energy spears and gets a clue that he must go to Roberta Sparrow's house. He takes Gretchen and two friends with him. They enter her cellar and are attacked by two guys with knives. A car arrives and swerves to avoid Roberta Sparrow, who is walking out carrying Donnie's letter. It misses her, but runs over Gretchen, who is lying down, killing her instantly. The two guys get out of their car. One of them is Frank, Elizabeth's boyfriend, in his Halloween rabbit costume. Donnie pulls a gun and shoots him through the eye, and then walks home carrying the dead body of Gretchen. He knows he has to redeem himself; he has to go back in time to undo this sequence of events. As the sun comes up, he decides to go up a hill to a lookout to watch a storm brewing and to look for a view of the portal forming in the sky above his house. Meanwhile Rose is coming home on the plane with her daughter and friends. The plane loses an engine, which falls through the sky and enters a portal, which causes it to go back in time about 28 days before it lands.

Donnie remembers Gretchen saying, "What if you could go back in time and replace all those hours of darkness and replace them with something better." He is able to turn back time, as we see a series of events from the film being played in reverse order until Donnie is lying in his bed as he was at the start to the film. The only thing left from the tangent universe is the falling jet engine. Donnie says to himself, "I hope that when the world comes to an end, I can breathe a sigh of relief because there'll be so much to look forward to." This time, he is laughing, either because he believes it was all a bad dream, or because he knows that he was meant to die this way. His sister comes in the front door, after being dropped off by boyfriend, Frank, who honks

his horn, probably to remind Donnie that they have been successful and to warn him to get out of the bed. However, he chooses to ignore the warning and the jet engine crashes through the roof as before, this time killing Donnie in his bed. He dies a hero because he has given his life to save Gretchen's and also because if he had allowed the tangent universe to collapse, it would have taken the primary universe with it. His family are all woken by the crash, with vague memories of the tangent universe they had just come from, like waking up from a bad dream. Gretchen rides past the accident scene on her bike and stops to find out what happened. She had not met Donnie at this point in the plot, so when asked by a young boy, she tells him that she never knew Donnie. She and Rose catch themselves looking at each other thinking that they have met somewhere before and exchange a wave.

My Comments: My first dilemma with this film was quite a difficult one to resolve: Is this a science fiction film, a psychological film, or both? These were mutually exclusive genres that I had created for the purpose of separating the films. Every other one of the 100 films in my data set belonged very clearly to just one genre. It definitely fell into the science fiction genre as the physics of wormholes was discussed along with the philosophy of time travel. However, because Donnie's therapist thought he was having daylight hallucinations, it could be argued that this was a psychological film and that the time travel never happened in reality, it was just in his imagination, as he was going insane. However, I was convinced it was science fiction after hearing director Richard Kelly on the audio commentary of the Director's Cut version of the film when he said, "There is no insanity; this is a science fiction story for me. [There] is a break in the spacetime continuum … it's unstable and Donnie has been chosen to save everyone … before the whole thing collapses on itself."

My next dilemma was: With the tangent universe collapsed, where does the jet engine come from at the end of the film? It cannot come from a future that no longer exists. When asked about this on the same audio commentary, Kelly says:

> Any time you do a time travel movie, you are going to have a paradox of some sort: something that can never fully make logical sense how it could occur. You could only justify it through speculation about the fourth dimension and what time is and how it wraps around itself.

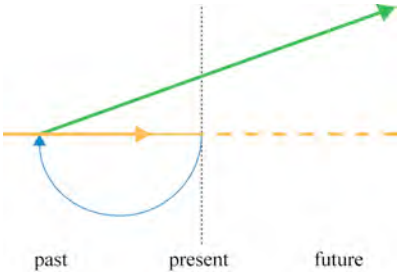
My interpretation is that the jet engine must come from somewhere, so it comes from the primary universe 28 days in the future. Its arrival combined with Donnie not dying in his bed causes the tangent universe to be formed. Donnie saved the universe by reversing time and staying in his bed so that the jet engine would kill him. This was his free will.

This issue of predestination is raised directly in this film. This is important, as it will determine which type of timeline is being used and hence the model of time. The spears of energy that Donnie can see propagating out of the solar plexus of various people show the direction that

they are about to walk. If Donnie can see where they are about to go and even where he is about to go before he has decided, then how much free will and choice do these characters have? His teacher said, "If we were able to see our destinies manifest themselves visually, then we would be given a choice to betray our chosen destinies. The mere fact that this exists would make all preformed destinies come to an end." Donnie suggests that if we follow God's path, then all time is pre-decided, but that obviously does not always happen.

Time Travel Summary: When Donnie arrived in his past, he made a different choice, which created a different future for everyone and hence a different timeline. My interpretation was that he restored the original timeline. Roberta Sparrow's book explains that the tangent universe is highly unstable, so eventually it will collapse upon itself, causing a black hole to be formed within the primary universe that is capable of destroying all existence. The tangent timeline is certainly an alternate timeline, but there is no evidence in the film to suggest that it could have existed in parallel to the primary line. It is more likely that the primary timeline collapsed and was replaced from that point on by the tangent timeline. Donnie then travelled back to the point of divergence and restored the original timeline by taking himself out of the equation, which was probably his original destiny. The model of time used in this film has an open past, open future with a diverging timeline, as shown in Figure 41.

The jet engine falls through a portal and arrives 28 days earlier, which creates a tangent universe:



Donnie travels back in time and his death allows the original timeline to be restored:

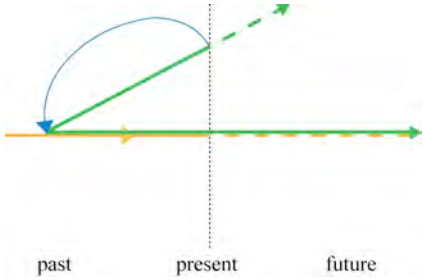


Figure 41: The first guyline graphs represents the jet engine's time travel, and the other Donnie's time travel, with both showing the resulting change to the original timeline

Note that the two-page summary of this review can be found on page 272 in Appendix I along with the two-page reviews of the other 99 films in the data set. A summary of the conclusions made in these reviews follows in Table 2.

Summary of results

	Film Title (Year)	Model of Time			Causal Loop
		Past	Future	Timeline	
1.	*Army of Darkness* (1992)	Open	Open	Converging	No
2.	*Austin Powers: International Man of Mystery* (1997)	Undefined	Open	Future	No
3.	*Austin Powers: The Spy Who Shagged Me* (1999)	Open	Open	Converging	No
4.	*Austin Powers in Goldmember* (2002)	Open	Open	Converging	No
5.	*Back To The Future* (1985)	Open	Open	Double Well	No
6.	*Back To The Future Part II* (1989)	Open	Open	Double Well	No
7.	*Back To The Future Part III* (1990)	Open	Open	Double Well	No
8.	*Biggles* (1986) aka *'Biggles: Adventures in Time'*	Closed	Closed	Fixed	Yes
9.	*Bill & Ted's Excellent Adventure* (1989)	Closed	Closed	Fixed	Yes
10.	*Bill & Ted's Bogus Journey* (1991)	Open	Open	Double Well	No
11.	*Black Knight* (2001)	Open	Open	Converging	No
12.	*The Butterfly Effect* (2004)	Open	Open	Double Well	No
13.	*The Butterfly Effect 2* (2006)	Open	Open	Diverging	No
14.	*Cashback* (2006)	Closed	Open	Diverging	No
15.	*A Christmas Carol* (2004)	Closed	Open	Diverging	No
16.	*Click* (2006)	Closed	Open	Diverging	No
17.	*Clockstoppers* (2002)	Undefined	Open	Diverging	No
18.	*A Connecticut Yankee In King Arthur's Court* (1949)	Open	Open	Converging	No
19.	*Contact* (1997)	Open	Open	Diverging	No
20.	*Daleks' Invasion Earth: 2150 A.D.* (1966)	Open	Open	Diverging	No
21.	*Déjà Vu* (2006)	Open	Open	Double Well	Yes
22.	*Demolition Man* (1993)	Undefined	Open	Future	No
23.	*The Devil's Arithmetic* (1999)	Closed	Closed	Fixed	Yes
24.	*Doctor Who* (1996) aka *'Doctor Who: The Movie'*	Open	Open	Double Well	No
25.	*Donnie Darko* (2001)	Open	Open	Diverging	No
26.	*Dr Plonk* (2007)	Undefined	Open	Converging	No
27.	*Durango Kids* (1999)	Open	Open	Double Well	No
28.	*Evil Dead 2* (1987) aka *'Evil Dead 2: Dead by Dawn'*	Closed	Closed	Fixed	Yes
29.	*Family Guy Presents Stewie Griffin: The Untold Story* (2005)	Open	Open	Double Well	No

30.	*The Family Man* (2000)	Undefined	Open	Parallel	No
31.	*The Final Countdown* (1980)	Open	Open	Converging	No
32.	*Flight Of The Navigator* (1986)	Undefined	Open	Diverging	No
33.	*The Forbidden Kingdom* (2008)	Open	Open	Converging	No
34.	*Forever Young* (1992)	Undefined	Open	Future	No
35.	*Freejack* (1992)	Undefined	Open	Double Well	No
36.	*Frequency* (2000)	Open	Open	Diverging	No
37.	*Galaxy Quest* (1999)	Open	Open	Diverging	No
38.	*The Girl Who Leapt Through Time* (2006) aka *'Toki o kakeru shôjo'*	Open	Open	Diverging	No
39.	*Groundhog Day* (1993)	Open	Closed	Diverging	No
40.	*Harry Potter and the Prisoner of Azkaban* (2004)	Closed	Closed	Fixed	Yes
41.	*Idiocracy* (2006)	Undefined	Open	Future	No
42.	*If Only* (2004)	Open	Open	Double Well	No
43.	*If Only…* aka *'The Man with Rain in His Shoes'* (1998)	Open	Open	Diverging	No
44.	*It's a Wonderful Life* (1946)	Undefined	Open	Parallel	No
45.	*The Jacket* (2005)	Undefined	Open	Double Well	Yes
46.	*Journey to the Center of Time* (1967)	Open	Open	Parallel	No
47.	*Jubilee* (1977)	Undefined	Open	Future	No
48.	*Just Visiting* (2001)	Open	Open	Diverging	No
49.	*Kate and Leopold* (2001)	Closed	Closed	Fixed	Yes
50.	*The Kid* (2000)	Open	Open	Diverging	No
51.	*A Kid in King Arthur's Court* (1995)	Open	Open	Converging	No
52.	*The Lake House* (2006)	Open	Open	Diverging	No
53.	*The Last Mimzy* (2007)	Open	Open	Converging	No
54.	*Lost Horizon* (1937)	Undefined	Open	Diverging	No
55.	*Lost In Space* (1998)	Open	Open	Diverging	No
56.	*A Matter of Life and Death* (1946) aka *'Stairway to Heaven'*	Undefined	Open	Diverging	No
57.	*Me Myself I* (1999)	Undefined	Open	Parallel	No
58.	*Meet the Robinsons* (2007)	Open	Open	Double Well	No
59.	*The Navigator: A Mediaeval Odyssey* (1988)	Undefined	Open	Diverging	No
60.	*The One* (2001)	Undefined	Open	Parallel	No
61.	*Peggy Sue Got Married* (1986)	Open	Open	Converging	No
62.	*The Philadelphia Experiment* (1984)	Undefined	Open	Converging	No
63.	*Philadelphia Experiment II* (1993)	Open	Open	Diverging	No
64.	*Planet of the Apes* (1968)	Undefined	Open	Future	No
65.	*Planet of the Apes* (2001)	Open	Open	Diverging	No

66.	*Playing Beatie Bow* (1986)	Open	Open	Converging	No
67.	*Premonition* (2007)	Closed	Open	Double Well	Yes
68.	*Retroactive* (1997)	Open	Open	Diverging	No
69.	*Returner* aka *'Ritana'* (2002)	Open	Open	Diverging	No
70.	*Run Lola Run* (1998) aka *'Lola Rennt'*	Open	Open	Diverging	No
71.	*Slaughterhouse Five* (1972)	Closed	Closed	Fixed	No
72.	*Sleeper* (1973)	Undefined	Open	Future	No
73.	*Sliding Doors* (1998)	Open	Open	Parallel	No
74.	*Slipstream* (2005)	Open	Open	Diverging	No
75.	*Somewhere In Time* (1980)	Closed	Closed	Fixed	Yes
76.	*A Sound of Thunder* (2005)	Open	Open	Double Well	No
77.	*The Spaceman and King Arthur* aka *'Unidentified Flying Oddball'* (1979)	Open	Open	Converging	No
78.	*Sphere* (1998)	Open	Open	Double Well	Yes
79.	*Star Trek IV: The Voyage Home* (1986)	Open	Open	Converging	No
80.	*Star Trek: First Contact* (1996)	Open	Open	Double Well	No
81.	*Star Trek: Generations* (1994)	Open	Open	Double Well	No
82.	*Stargate: Continuum* (2008)	Open	Open	Diverging	No
83.	*Suddenly 30* (1995) aka *'13 Going on 30'*	Undefined	Open	Diverging	No
84.	*Superman* (1978)	Open	Open	Diverging	No
85.	*Teenage Mutant Ninja Turtles III* (1993)	Open	Open	Converging	No
86.	*The Terminator* (1984)	Open	Open	Diverging	Yes
87.	*Terminator 2: Judgement Day* (1991)	Open	Open	Diverging	No
88.	*Terminator 3: Rise of the Machines* (2003)	Open	Closed	Converging	No
89.	*Time After Time* (1979)	Undefined	Open	Converging	No
90.	*Time Bandits* (1989)	Closed	Closed	Fixed	Yes
91.	*Time Changer* (2002)	Undefined	Open	Double Well	No
92.	*The Time Guardian* (1987)	Open	Open	Converging	No
93.	*The Time Machine* (1960)	Closed	Closed	Fixed	No
94.	*The Time Machine* (2002)	Open	Open	Converging	No
95.	*Timecop* (1994)	Open	Open	Double Well	No
96.	*Timeline* (2003)	Open	Open	Converging	No
97.	*TimeQuest* (2002)	Open	Open	Diverging	No
98.	*Timescape* (1992) aka *'Grand Tour: Disaster in Time'*	Open	Open	Double Well	No
99.	*Twelve Monkeys* (1995)	Closed	Closed	Fixed	Yes
100	*Vanilla Sky* (2001)	Undefined	Open	Future	No

Table 2: A summary of the model of time used in each of the 100 reviewed films

Discussion

Past-future rules

As can be seen from Figure 42, the past was changeable for more than half of the films. Only 15 of the films used a rule where the past was closed. A quarter of the films had an undefined past because no time travel into the past took place, nor was there any mention of it. This did not mean that the past was open or closed; it just meant that the rule used in the past was not defined. So out of the 76 films whose past was defined, 61 of them used an open past, which is more than 80% of the films. The pie chart in Figure 43 shows that 87% of the films used an open future rule.[1]

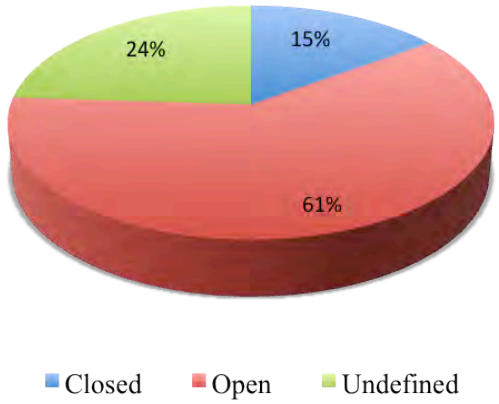


Figure 42: Number of films with a closed, open or undefined past

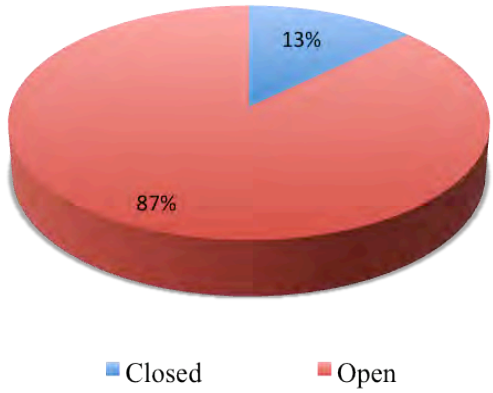


Figure 43: Number of films with a closed or open future

It makes for an interesting storyline if the past and future are open because it means that everything the characters do could change the future, which increases the number of options for plot development. This is not to say that a film with a closed past and closed future is not a good film, it is just a different type of film. Just because the future is closed, it does not mean that the characters or the audience know what the predestined future will hold; what it does mean is that nothing the characters do will change anything in the future. However, in films with a causal loop, whatever the characters do

[1] There was not a category for 'undefined future' because the future is affected by changes to the past, and therefore always defined by it, whereas the past is never affected by changes to the future.

in the past will actually cause the predestined present and future to take place in the way it is supposed to.

The bar chart shown in Figure 44 combines these results to show how time is treated in the different films. The most dominant films were the ones with an open past and open future such as *Back to the Future Part II* (1989). These films are the easiest films for a scriptwriter to pen because they can instantly change anything at any time to make an exciting plot. They are usually full of paradoxes, which are conveniently glossed over and almost never addressed.

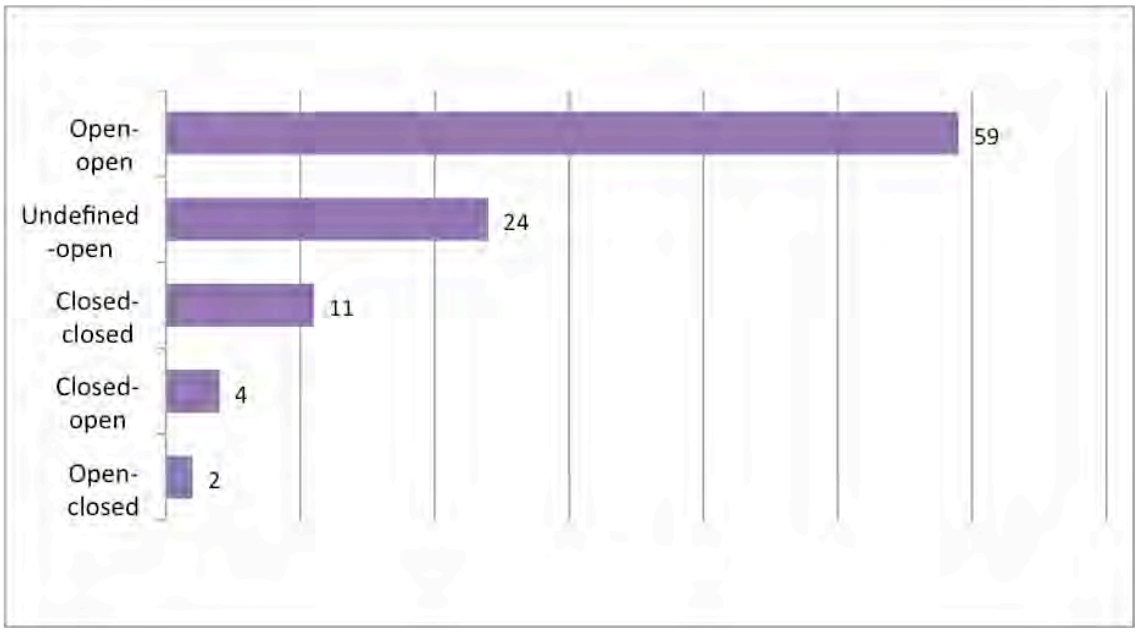


Figure 44: Number of films that use each past-future rule

A quarter of the films have an undefined past and an open future such as *Planet of the Apes* (1968). These are the films where the characters travel to the future, but never to the past. Most of these films are about people from the present experiencing life in a future world, so time travel is just a plot device used to take them there.

11 films of my data set used the rule where films have a closed past and a closed future. For these scripts to work, they need to be tighter because all of the temporal paradoxes need to be resolved in order for the plot to remain self-consistent, so the timeline can be totally closed. This type of film often has causal loops, which need to be carefully worked out such as *Twelve Monkeys* (1995).

Only four of the films in my data set had a closed past with an open future. The film I used as an example was *Click* (2006), but an equally good example is *A Christmas Carol* (2004). This is such a successful story: I identified more than 20 other film adaptations made of this book.[1] I was surprised more films had not been made using this same model of time, but with a different story. I wrote up a full review of only one film adaptation of the book because they all followed the same plot and all used the same model of time. However, if I had included more of these adaptations, this rule would have scored more highly in the bar chart.

The final rule was the one where films had an open past and a closed future. *Groundhog Day* (1993) and *Terminator 3: Rise of the Machines* (2003) were the only two films that used this rule. In the first, the future was considered closed because every other future Phil tried to create ended up with him being thrown back in time. That is not to say that there was a second or third type of future that would have worked. However, the implication was that this was the only timeline that was going to take him into the future. In the second, it is not so much the future that is fixed, but the event that caused the terminator to be sent back. That had to happen in order to avoid a paradox thus keeping the timeline self-consistent. So once this event has passed, the future could from that point on be open to change. The important difference though is that the future is not totally open.

Types of timeline

Figure 45 shows how many films used each different type of timeline:

[1] See a list of them all in 'Films based on *A Christmas Carol*' on page 441 in Appendix II.

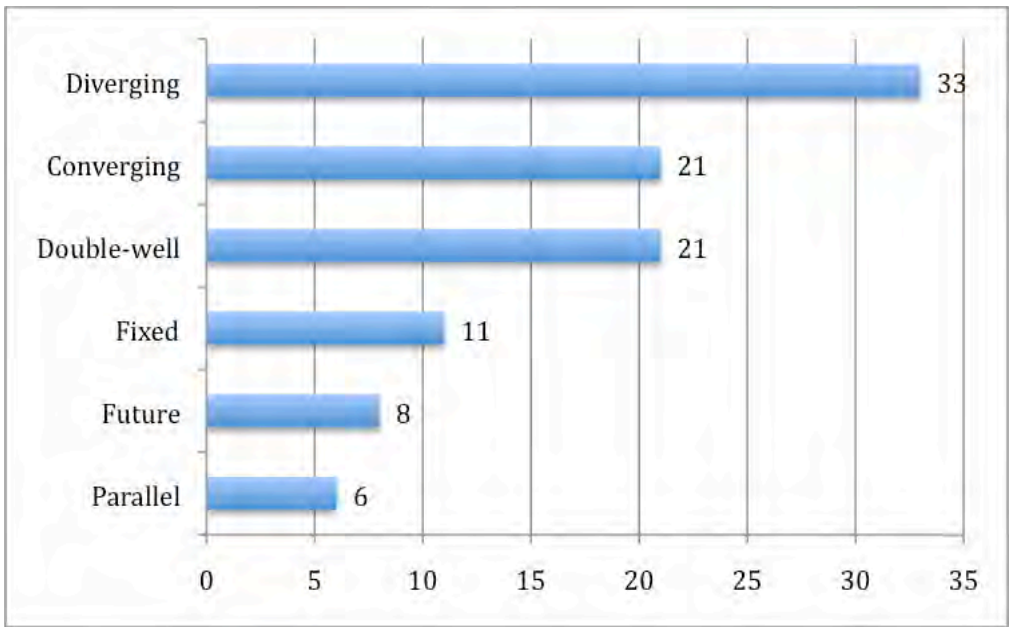


Figure 45: Number of films for each type of timeline

The diverging timeline was used in 33 of the films such as the previously discussed films, *The Butterfly Effect* (2004) and *Terminator 2: Judgement Day* (1991). As it replaces the original timeline from the point the time traveller arrives in the past, it is a type of replacement timeline. The converging timeline, as used in *Terminator 3 - Rise of the Machines* (2003), was used in 21 of the films. As noted earlier, a converging timeline is a timeline that diverges, but comes back, so it is another type of replacement timeline. 21 of the films used the double well timeline, such as *Déjà Vu* (2006) and the *Back to the Future* trilogy. This is a timeline that diverges, then converges and has the potential to diverge again, so is another type of a replacement timeline. Therefore three quarters of the films in the sample employed one type of replacement timeline or another.

A fixed timeline was used in 11 of the films, like *Slaughterhouse Five* (1972) or films with causal loops such as *Twelve Monkeys* (1995). This type of timeline has a closed past and a closed future, so that all events are predetermined.

Eight of the films used a future timeline, such as *Austin Powers: International Man of Mystery* (1997). As previously mentioned, this is not really a type of timeline; it is a film that we do ot know enough about to determine which type of timeline was used.

Six films used a parallel timeline, such as *Sliding Doors* (1998). As previously stated, a parallel timeline could diverge, converge or remain fixed, however the point is that the original timeline remains unchanged.

Models of time

The above diagrams include films with an undefined past or a future timeline. These films do not contain enough information in order to determine the full model of time being used. So if these are removed from the data set, this means only films using the four original past-future rules and five types of timeline will be taken into account. Figure 46 shows that by combining the four past-future rules with the five types of timeline, it can be seen that nine different models of time were found in the data set:

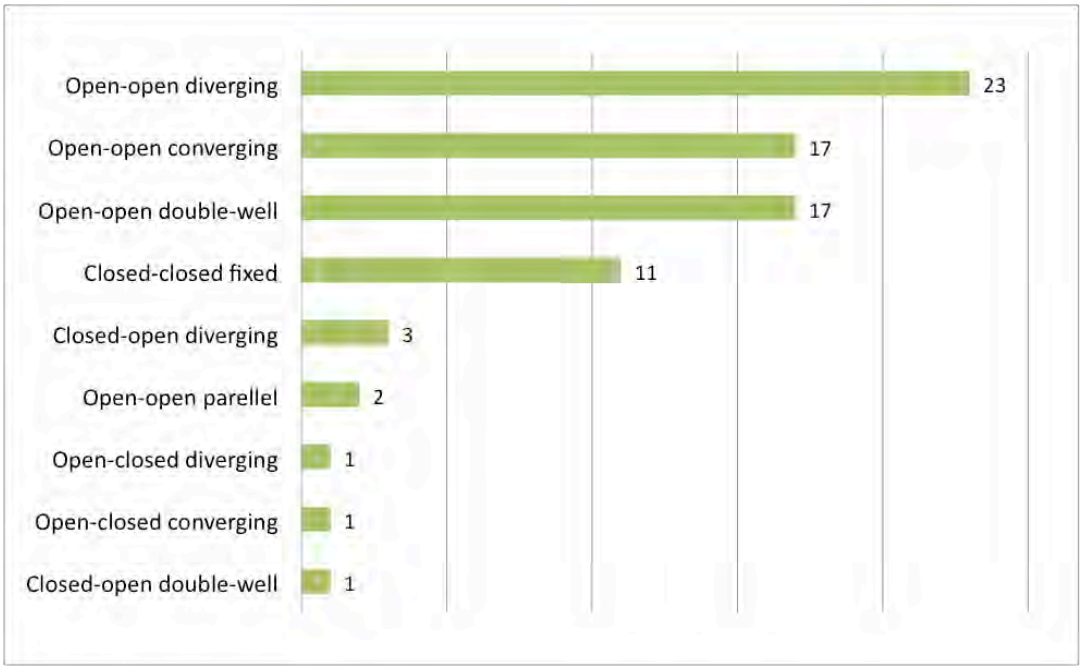


Figure 46: Number of films that used each model of time

If the four past-future rules are combined with the five types of timeline, a matrix of 20 potential models of time can be formed as shown in Table 3. In each square of the matrix, a guyline graph is included as an example of one of the possible timelines that could exist for that model of time. The number that appears in each square in a dark red colour represents the number of films in my data set that used that particular model of time.

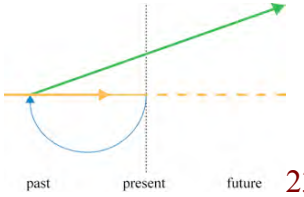
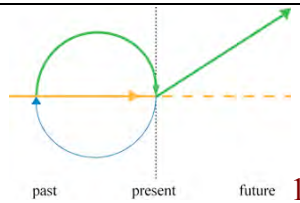
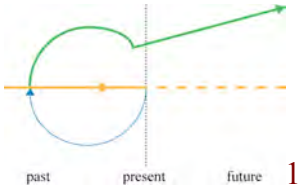
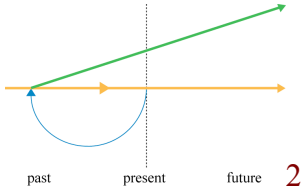
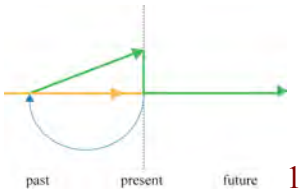
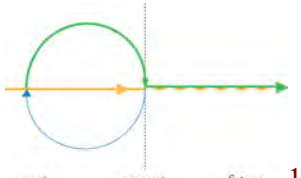
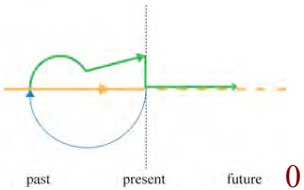
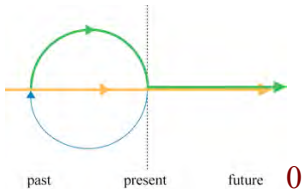
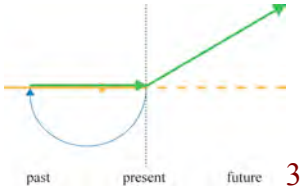
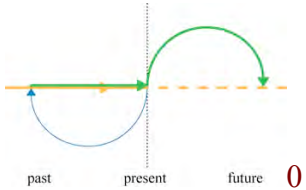
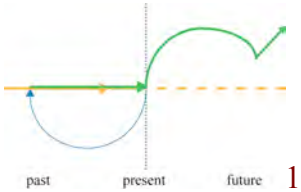
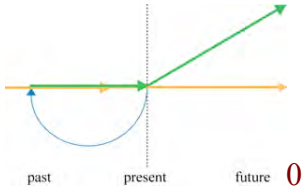
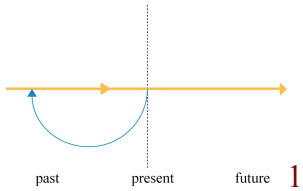
Rule	Diverging timeline	Converging timeline	Double well timeline	Parallel timeline	Fixed timeline
Open past, open future	 23	 17	 17	 2	Not possible
Open past, closed future	 1	 1	 0	 0	Not possible
Closed past, open future	 3	 0	 1	 0	Not possible
Closed past, closed future	Not possible	Not possible	Not possible	Not possible	 11

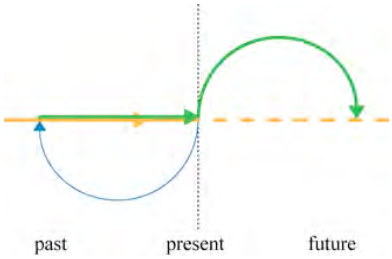
Table 3: A matrix of the different models of time showing the number of films that used each model

The missing models of time

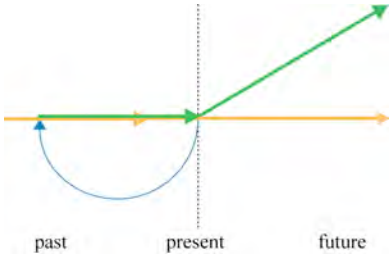
As can be seen in Table 3, there were seven models of time that were not possible. Any version of a fixed timeline that allows for a changeable past or future cannot be fixed in time, and is therefore not logically possible. Likewise any version of the other timelines that does not allow for any form of openness in either the past of the future is by definition a fixed timeline as no events are being replaced.[1]

Therefore, there are only 13 models of time that are possible in reality, and as I had identified nine of them in my data set, this meant that there were another four possible models that were missing:

1. Closed past, open future with a converging timeline.
   In this model of time, whether the time traveller interacts with the past or just observes it – they are unable to change it. They do however gain information while there, so on their return to the present, they can then use this to change the future, thus causing the timeline to diverge and replace the original. However, the timeline eventually converges back to join the path of the original timeline.

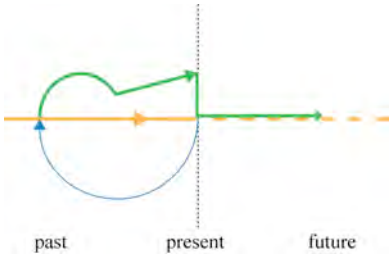


2. Closed past, open future with a parallel timeline.
   In this model of time, the future section of the new timeline could be converging (as above), diverging or a double well, so long as the original timeline remains unchanged and in parallel to the new one. Note that the two parallel timelines in the past (before the point in time when the time travel journey begins) are actually one and the same.

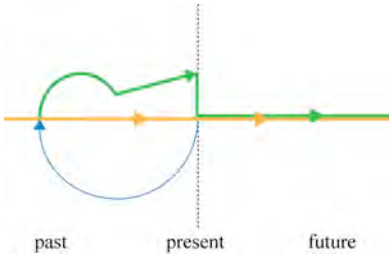


[1] The parallel timeline with a closed past, closed future is deemed to be impossible here; however, it is shown to be possible in Chapter Six, see Figure 58 on page 185 and the paragraph that precedes it.

3. Open past, closed future with a double well timeline.
   In this model of time, the timeline is the same as a double well timeline with an open past and open future, where the new timeline replaces the original one. However, when it reaches the time traveller's point of departure (the present) there can only be one possible future from that point on, so the future timeline joins the path where the original timeline would have been.



4. Open past, closed future with a parallel timeline.
   In this model of time, the past section of the new timeline could be a double well (as above), converging or diverging, so long as the original timeline remains unchanged and in parallel to the new one. However, when it reaches the time traveller's point of departure (the present) there can only be one possible future from that point on, so the two parallel timelines in the future are actually one and the same.



A film could be made using any of these four models above and may exist in the list of films that I identified but did not review (see Appendix II). In order for a researcher to confirm that any of the above four models of time were being used in a film, the time traveller in the film would have to have seen the future before they made the journey to the past, so that he or she could make a comparison between the original future and the new one they were creating. Alternatively, in the case of the models with parallel timelines, the audience would need to have had glimpses of the parallel timeline in the future for a comparison to be made - as happened in *Sliding Doors* (1998).

When time travellers go back in time and change the past, they know whether a change has occurred because they can compare the new events to the ones they have read about in history books. As time travellers do not have access to history books about the future, they have nothing to compare the events with that they are changing in the future. Unless of course a time traveller came back through time from our future with their history book, which is of course what happened in *Back to the Future Part II* (1982) when Biff came back through time carrying his sports almanac from the future.

Summary

My research led me to discover 444 films that potentially included time travel. After watching and reviewing more than 100 films, a data set of 100 films was formed, and it was established that it was possible to determine a complete model of time for 76 of the films. When this data subset was analysed, four different past-future rules were identified:

1.	open-open	59 films	78 %
2.	closed-closed	11 films	14 %
3.	closed-open	4 films	5 %
4.	open-closed	2 films	3 %

Five types of timeline were also identified: three types of replacement timeline, a parallel timeline and a fixed timeline: [1]

1. Diverging timeline - 27 films (36 %)
   Time travel to the past causes a new timeline to replace the original one, and it diverges away towards a different future.

2. Converging timeline - 18 films (24 %)
   Time travel to the past causes the original timeline to be replaced by a new one, which initially diverges away towards a different future, but eventually comes back towards the original timeline joining it at some point before the time travel began.

3. Double well timeline - 18 films (24 %)
   Time travel to the past causes a new timeline to replace the original one, and it initially diverges away towards a different future, but eventually comes back towards the original timeline. However, given a sufficiently significant intervention, it could then either diverge away again, or join the original timeline at some point before the time travel began.

4. Parallel timeline - 2 films (3 %)
   Time travel to the past causes a new timeline to form alongside the original timeline. The new timeline could be a diverging, converging or

[1] Due to rounding, the percentage figures do not add up to exactly 100%.

double well timeline, but the important difference here is that the original timeline remains untouched.

5. Fixed timeline - 11 films (14 %)
   Time travel to the past causes no changes to be made to the timeline. In the case of a causal loop, any actions that appear to be making changes are not making changes at all; they are causing the present to take place. This timeline is synonymous with the closed past and closed future rule.

There were also eight films that had what I called a 'future timeline' because although they contained time travel to the future, they had no backwards time travel. This was not a type of timeline, rather a way of categorising films that had not enough information present to establish which type of timeline was being used.

A matrix of the four past-future rules and the five types of timeline generated thirteen possible models of time. The filmmakers in my data set had used only nine of these models, which meant that four of the models were not used in any of the films.

In the following chapter I describe three focus groups designed to uncover how these models of time compare with the personal models of time being used by members of the movie-going public – both physicists and non-physicists. The results of this chapter and the following chapter are then compared and synthesised in Chapter Six.

CHAPTER FIVE: INTERVIEWS

> *Time is free, but it's priceless. You can't own it, but you can use it. You can't keep it, but you can spend it. Once you've lost it you can never get it back.*
>
> - Harvey MacKay, author and motivational speaker[1]

Having obtained 13 different models of time travel from analysing the 100 film reviews of Chapter Four, I then wanted to discover how these models compared with the personal models of time travel being used by members of the movie-going public.

I assumed that most people (but not all) had at some point stopped to contemplate their perceptions of time. Indeed, how many, who had not studied time at an academic level, had ever stopped to consider the true nature of time? If they had, what had they concluded?

The main aim of this part of my research was to confirm that the movie-going public could relate to the models of time travel that I identified in the films and to find out which of them most closely represented their personal model. This was achieved using focus group interviews where the participants discussed at length my two key questions:

1. Which past-future rule most closely represents how time really works for you?
2. Which type of timeline most closely represents how time really works for you?

By combining the answers from both questions, a model of time for each participant was constructed.

Another aim was to encourage discussion about my models of time, which might cause new models to emerge that I had not yet considered.

A subsidiary aim of this study was to find out how the beliefs of the focus group participants who have studied the physics or philosophy of time at an academic level differed from those who had not.

[1] MacKay (2009).

For the first and third focus groups, participants were not invited if they had studied the physics or philosophy of time at an academic level, while this was mandatory for the second focus group. All participants were required to have previously watched some time travel films.

Overview

The following methodology section explains how I chose a suitable method, how and why the interviews were set up, along with the design of the focus group questions. The results and analysis section is a summary of the highlights from each of the three focus group interviews. It analyses what the participants had to say about the four past-future rules and the different timelines. Their choices are tabulated within each section. The discussion section looks at the popularity of each model of time travel, and compares the choices of the physicists against the non-physicists. This chapter ends with a short summary of the findings of this study, which draws conclusions arising out of the discussion of the results and responds directly to the aims of the study.

Note that Appendix IV contains transcripts of the main parts of the three focus group interviews and also of the one-on-one interview.

Methodology

Choosing a method

My first task was to choose a suitable method for achieving an answer to my research questions. There were several possibilities from which to choose: I could have used one-on-one interviews, focus group interviews or a survey.

I began by designing a questionnaire for use in a survey to find out which beliefs the movie-going public held about the models of time. I considered a series of questions similar to the following:

- Do you think the timeline is malleable in the past?
- Do you think the timeline is malleable in the future?

However, the problem was that respondents could have been very superficial in their answers if they had not thought this through thoroughly enough to form a considered opinion. I wanted the respondents to think about the models in time travel films they

had seen, and to then stop and consider which of these models most closely represented their personal model of time travel.

Kitzinger & Barbour (1999, p. 128) confirmed my doubts by stating, "In general, questionnaires are more appropriate for obtaining quantitative information and explaining how may people 'hold' a certain (predefined) 'opinion'. However, focus groups are better for exploring how points of view are constructed and expressed." One definition of a focus group is "a small (6-12 member), relatively homogeneous group that meets with a trained moderator who facilitates a 90- to 120-minute discussion in a non-threatening, relaxed environment about a selected topic" (Bers, 1989, as cited in Pickering & Watts, 2005).

Another advantage of focus group discussions "is that the format allows the moderator to probe. This flexibility to explore unanticipated issues is not possible within the more structured questioning sequences typical of … surveys" (Krueger, 1994, p. 35).

One-on-one interviews would have addressed this problem, but Marshall & Rossman (1995, p. 84) suggest that "people often need to listen to others' opinions and understandings in order to form their own. One-on-one interviews may be impoverished because the participant had not reflected on the topic and feels unprepared to respond." In a one-on-one interview the participant would only have one person with whom to discuss their ideas, whereas a focus group interview would give the participants close to an hour to discuss the topic with their peers, to listen to other's points of view and to articulate their own. They would then be able to come to a decision about which model of time they thought most closely represented their personal model of time. As a result of this discussion, it would still be possible for them to revise their model of time from the one they initially held.

Another advantage of a focus group is, "Inhibitions often are relaxed in group situations, and the more natural environment prompts increased candor by respondents" (Krueger, 1994, p. 34). The main disadvantage of a focus group over a one-on-one interview is that the researcher has less control, as "group members are allowed to influence the course of the discussion, [which] results in some inefficiencies such as detours in the discussion, and the raising of irrelevant issues" (p. 36). However, I concluded that the advantages outweighed the disadvantages, so I proceeded by setting up a number of focus group interviews.

My research method

Saha (2008) explained that focus group interviews can be used as:

- a stand-alone research method,
- a method of finding out what issues are crucial before formulating survey questions,
- a method to verify results of already completed research.

My initial intention was to use the focus groups for the latter, as I had nearly completed the main part of my research by formulating the models of time from the film reviews. However, as my models were still evolving, the focus groups were also going to be used to create discussion around my existing models of time, which might cause new models to emerge that had not yet been considered.

Crandall (1999) wrote: "because of its open and exploratory nature, focus-group research can also stimulate discussion about ideas not anticipated, or topics not included in the discussion guide used by the moderator." Therefore focus groups would also be a suitable way to address my second subsidiary aim, which was to elicit unexpected ideas concerning the existing models of time travel, which might cause new models to emerge that had not yet been considered. Shaw (1999, p. 156) agreed, "The co-participants act as co-researchers taking the research into new and often unexpected directions and engaging with each other in ways which are both complementary … and argumentative." He added that they also "introduce a valuable approach to learning the extent of consensus on a particular issue."

Saha (2008) explained, "Focus groups can be confirmatory, or exploratory in nature." Mine were going to be both: I wanted to confirm that they could understand the models of time that I had identified in the films; in addition, I wanted to find out which of them most closely represented their personal model of time travel.

When moderating (also known as facilitating) the focus group interviews, it took great self-discipline to avoid interrupting the participants if I did not agree with them. Krueger (1994, p. 102) explained that researchers "who have a personal commitment to the topic of inquiry need to be particularly careful to suspend their personal views and seek out the perceptions of the group participants." Cribb and Hartomo (2002, p. 183) suggested "the best approach is not to pose questions, but rather to let conversation flow

among the group on the general topic, allowing them to show what they do and do not know how they feel about an issue." So it was important not to be an interviewer, but rather to be a facilitator guiding the group along productive lines.

Pickering and Watts (2005) suggest that the moderator employs an assistant moderator whose responsibilities are as follows:

> Supports the Moderator in setting up equipment and organizing the interview room. During the interview monitors equipment, welcomes late-comers and resolves interruptions. Takes notes throughout the discussion for the purpose of debriefing (as negotiated with the Moderator). Does not take part in the discussion unless exceptionally requested. Looks through notes and summarises key points/issues. Contributes to debriefing immediately after the interview. Supports ongoing data analysis process.

Krueger (1994, pp. 124-125) has a list of "Rules for Assistant Moderators" that I photocopied and handed out to each assistant moderator several days before the focus group took place, so that they understood what I was expecting of them. It also made sure that each interview was as consistent as possible, so as to minimize variables between the different focus group interviews.

Structuring the study

Selecting the type of participants for a focus group interview is a major consideration: Knodel (1993, p. 40) states, "Holding separate sessions with homogeneous but contrasting groups is believed to produce information in greater depth than would be the case with heterogeneous groups." Kreuger (1994, p. 77) comments, "The focus group is characterised by homogeneity but with sufficient variation among participants to allow for contrasting opinions." Homogeneity can be achieved by composing groups based on occupation, educational level, age, gender, ethnicity or socio-economic factors, in order that sharing within the group discussion can be enhanced (Saha, 2008). Also, a homogeneous group would allow the researcher to learn "the extent of consensus on a particular issue" (Shaw, 1999, p. 156). It is important to make sure that there are no power relationships involved, as this can cause a group member to be afraid to speak their truth, and/or to say what they think they are expected to say, or just to agree with their superior to gain favour (Saha, 2008).

Kitzinger & Barbour (1999, p. 7) point out, "It is also useful to develop a topic-specific sampling strategy." I therefore decided that one of my focus groups would consist of participants who all had a university degree in physics while the other focus groups

would have no participants that had studied the physics or philosophy of time at an academic level.

Selecting the number of participants for each focus group interview is also important. Kreuger (1994, p. 78) suggests, "The traditionally recommended size of the focus group has ranged from 6 to 12 participants [however] the ideal size of a focus group typically falls between 6 and 9 participants." As there are always last-minute cancellations, I invited ten participants to each session; my three focus group interviews ended up with seven, nine and eight participants respectively.

"Focus group studies range from just three or four groups, to over fifty… Statistical 'representativeness' is not the aim of most focus group research" (Kitzinger & Barbour, 1999, p. 7). This certainly was not my aim. My plan was to hold a practice focus group to refine my technique and test my key questions, followed by at least three groups, which would be used for data collection. Kreuger (1994, p. 88) suggested continuing "conducting interviews until little new information is provided or when you have reached theoretical saturation."[1] The procedure undertaken during the interviews is described in detail later.[2]

The pilot focus group

I chose to use the following questioning structure for my focus group as recommended in Kreuger (1994, p. 54).

1. Opening Questions
2. Introductory Questions
3. Transition Questions
4. Key Questions
5. Ending Questions

I ran a pilot focus group on 18 September 2008, when it was my turn to host the fortnightly meeting of the Science Communication PhD students at the Centre for the Public Awareness of Science at ANU. I asked for and received feedback from the staff and students present, as some of them had experience in this type of research.

[1] *Theoretical saturation* is a concept coming from grounded theory, which was described by Glaser and Strauss (1967). Sampling continues until each category of investigation is saturated.

[2] See the section 'Procedures' on page 148 of this chapter.

Kreuger (1994, p. 69) suggested that the first focus group interview could be a pilot test after which: "The moderator should reflect once again on the wording and sequencing of the questions." I used the audio recording of the session for this reflection, and the lessons that I learnt were that:

- It is easy to fall into using jargon with which the participants are not familiar.
- Not everyone would necessarily be aware of their personal model of time - they might need some discussion and thinking time before deciding.
- The structuring of the questions is critical: introductory and transition questions are needed to gently lead the participants to the key questions.
- Timekeeping is imperative: I allowed the introductory and transition questions to go on for too long, which had not left enough time for the group to fully discuss my key questions.
- I was going to have to use two separate key questions, which would each need a separate transition question.

Kreuger (p. 107) recommended between two and five keys questions, so I chose to include two of them, therefore my questioning structure was modified as follows:

1. Opening Questions
2. Introductory Questions
3. First Transition Questions
4. First Key Question
5. Second Transition Questions
6. Second Key Question
7. Ending Questions

The introductory questions

These questions were designed to initially settle the participants, to introduce the subject of time travel in films, and to get the group talking. Following are examples of introductory questions that I used:

- How often do you watch a movie and is it usually on TV, rented, streamed, or at a cinema?
- Can you remember watching any movies that involved time travel or other temporal phenomena, and if so, which ones were you favourites and why?
- Do any other films immediately spring to mind?

The first transition questions

These questions were used to introduce the idea that different past-future rules existed. The participants were given different well-known time travel films to discuss and compare. They were then asked how the past and the future were treated differently in each film, or not, as the case may be. If any of the participants had not previously thought seriously about their personal model of time, then using films would provide a context or trigger to provoke such thinking. The idea was that they would eventually realise that each film had used a different past-future rule. There were only two films to discuss in the first focus group interview; however, the subsequent interviews had four films to discuss because by then, four different past-future rules had emerged:

- Open past, open future: *Back to the Future Part II* (1989)
- Open past, closed future: *Terminator 3: Rise of the Machines* (2003)
- Closed past, open future: *Click* (2006) or *A Christmas Carol* (2004)[1]
- Closed past, closed future: *Slaughterhouse Five* (1972)

The first key question

'Which past-future rule most closely represents how time really works for you?'[2]

By each participant deciding which of the films most closely represented their personal model of time travel, they would be telling me whether they believed the future to be open (changeable) or closed (fixed), and whether they believed that the past was open or closed.

In the first focus group interview, the participants were asked whether they thought *Slaughterhouse Five* (1972) or *A Christmas Carol* (2004) most closely represented their personal model of time. By the time the next focus group had taken place, two more

[1] Both of these films use the same model of time. *A Christmas Carol* (2004) was used as the example in the first focus group and *Click* (2006) was used in all of the subsequent interviews.

[2] In some of the interviews the term 'category of time' was used in place of 'past-future rule'.

past-future rules had emerged, so the participants from then on were given four films from which to choose (each of which represented a different past-future rule).

The second transition questions

These questions were used to introduce the idea that different types of timelines existed. The participants were asked if backwards time were possible, what would happen when the time traveller arrived? They were given another set of well-known time travel films, so that they could discuss and compare the plots of them and deduce the types of timeline used in each. There were only two films to discuss in the first focus group interview; however, the subsequent interviews had four films to discuss because by then four different types of timeline had evolved:

- Parallel timeline: *Sliding Doors* (1998)
- Diverging timeline: *The Butterfly Effect* (2004)
- Converging timeline: *Terminator 3: Rise of the Machines* (2003)
- Double well timeline: *Déjà Vu* (2006)

The second key question

'Which type of timeline most closely represents how time really works for you?'

The timelines were also continually evolving. In the first focus group interview, the second key question was described as: 'Which of these two movies [*Sliding Doors* and *The Butterfly Effect*] do you think most accurately represents how time works in reality?' Or, put another way, 'If backwards time travel were possible, do you think your arrival would be changing the original timeline, or do you think it would be creating a new one in parallel?'

Before the second focus group interview, the converging timeline had already emerged from the theory, so *Terminator 3: Rise of the Machines* was added to their choices. The double well timeline was just emerging from the theory, so *Déjà Vu* was discussed at the end of the second focus group. In the third focus group, it was added to the list of films the participants could choose from up front.

The ending questions

The answers from the two key questions produced a model of time travel for each participant. Krueger (1994, p. 55) suggested asking the participants to "state their final

position on critical areas of concern" at this stage of the interview, and wrote that "[o]ften this question is asked in a round robin manner." I adopted the round robin questions after the first focus group, as I found this to be a more effective way of making sure that I understood which of my models of time travel each participant believed was closest to their own personal model. At the end of the interview I asked the assistant moderator to summarise what they thought the participants had said, and I asked them if there was anything else that they would like to add. It was at this point that the participants were given the opportunity to mention if their personal models of time travel did not match any of the models that had emerged from the films. The assistant moderator was then given an opportunity to make a comment or ask a question to the group.

Ethics approval

My Human Ethics protocol (2008/340 'Models of Time') received approval by the Deputy Chair of the Human Ethics Research Committee on 17 August 2008. As part of this application, the following documents were approved.[1]

- A letter of approach to be sent in advance to the club or institution
- An information sheet for participants
- An oral consent script

Each focus group was started by me reading out the oral consent script, which contains a series of questions. Everyone was asked to reply to them verbally, so their answers could be picked up on the audio recording.

The first focus group interview

I wrote a letter to the president of the ANU Toastmasters Club asking if their members would like to help me with my research by participating in one of my focus groups interviews about 'Models of Time'. The response was positive; so I gave him some information sheets to hand out to prospective participants at their next meeting.

The focus group interview took place directly after a Toastmasters Club lunchtime meeting using the "piggyback" method of adding a focus group to the end of another meeting, as recommended by Kreuger (1994, p. 83). Six of the seven members that

[1] These documents and the ethics approval can be viewed in Appendix III, which begins on page 455.

participated were retired or semi-retired Australian academics, which meant that the seventh member had less in common, as she was an Asian undergraduate student. I noticed that she was much less vocal than the others and only spoke when asked a direct question. There were no power relationships in play amongst the others - as per the recommendation of Saha (2008).

When analysing the discussions of this focus group interview, I was not able to discern the model of time chosen by some of the participants. This was not because they had trouble deciding; it was because I had not used the round robin questions during the ending questions to gain a direct answer to the two key questions. Therefore, for each of the remaining interviews I conducting a verbal survey after each group discussion had finished. I asked the participants in turn which past-future rule and which timeline most closely represented their personal model of time.

The second focus group interview

All of the participants of this group had studied relativity and quantum mechanics. This meant that most were familiar with parallel universes as a possible interpretation of quantum mechanics, curved spacetime, time dilation, and non-simultaneity. This implied a sophisticated understanding of the physics of time. They were all in their 20s, and were either doing research or other work within the Department of Physics at ANU, so they all knew (or knew of) each other. There was one exception: he was a retired engineer and former physics lecturer from the University of Canberra, but this was not a problem as he was an active participant and fitted in very well with the group.

The third focus group interview

The following week, I was going to The University of Otago in Dunedin, New Zealand for the week to visit their Centre for Science Communication, which specialises in science documentary filmmaking and natural history. Before leaving, my host in New Zealand, Professor Jean Fleming, offered to organise ten focus group participants for me in Dunedin, so that I could hold my third focus group interview while there, and she also agreed to be the assistant moderator on the day. What all the participants had in common was that they all knew her, but did not necessarily know each other and they were mostly in their 30s. They had either a biology or film background, which made an interesting mix.

The one-on-one interview

There was one potential participant in Dunedin who was a filmmaker and a big fan of time travel films, who was very keen to attend the focus group; however, he had to teach at that time, so I offered to interview him alone prior to the focus group. I recorded our conversation, which covered the same questions that I was going to ask in the focus group interview later that day. I had to modify the oral consent slightly, but other than that, I followed virtually the same format.

Interview		**Focus group I**	**Focus group II**	**Focus group II**	**One-on-one**
Date		28/08/08	30/10/08	4/11/08	4/11/08
Participants		Members of ANU Toastmasters	Physics Graduates at ANU	Biologists & filmmakers in Dunedin	Filmmaker in Dunedin
Number of participants		7	9	8	1
Past-future rules	closed-closed	X	√	√	√
	open-closed	X	√	√	√
	closed-open	√	√	√	√
	open-open	√	√	√	√
Types of timeline	parallel	√	√	√	√
	diverging	√	√	√	√
	converging	X	√	√	√
	double well	X	√	√	√

Table 4: A summary of the different past-future rules and types of timeline that were given as choices at each interview

Procedures

The day before each interview, I sent an email to every participant, which I copied to the assistant moderator, reminding them all of the time and the place, and asking them to be on time because we would not be able to start until everyone was there. This served two purposes, "It reinforces the importance of the group … and it reminds participants who might have forgotten about the session" (Krueger, 1994, p. 90).

After experimenting with various external microphones, I found that the internal omnidirectional microphone in my MacBook computer worked just as well as any

others, so that is what I used for the audio recording of every focus group. In case the computer failed during the session, I always brought my second choice, a small portable iRiver mp3 recording device with me as a back up. I placed the MacBook in the middle of the table facing me, so that I could keep an eye on the recording levels. I chose to use Apple's Garage Band software to record the sessions, setting recording levels to 'auto'.

I followed the seating arrangements recommended by Saha (2008) and Krueger (1994, p. 124): I had everyone sit around a large table with me at the head and with the door opposite me. The assistant moderator sat near the door at a separate desk, which was outside of the circle, but close enough to be able to see everyone and their reactions. This meant that I did not put a chair in the space in front of the assistant moderator, so he or she could clearly see everyone. The third focus group in Dunedin was slightly different, as there was no large table. Instead, each chair had a flap that could be lifted up to provide a writing surface. I arranged the chairs beforehand in an oval shape, so that each person was sitting where they would have been, if they had been sitting around a large oval table. A small coffee table was placed in the middle of the oval with my MacBook on it, so that the microphone was equidistant from everyone and could record all of the voices equally clearly.

In order to be as consistent as possible, I always tried to minimise the variables in each of the focus groups. A couple of jugs of water were always placed in the middle of the table along with a full glass of water at everyone's table place. I also put a plate of chocolate biscuits at each end of the table and encouraged them to pass the plates around at a couple of points during the session. I was careful not to include any crunchy items that would adversely affect the sound quality of the audio recording.

"Incentives are needed because participation in a focus group requires time and effort…. It serves as a stimulus to attend the session…. Amounts of $20 to $50 have been found to be an efficient range for public and nonprofit studies" (Krueger, 1994, pp. 91-92). I chose a double movie pass for use in a local cinema as an honorarium because this fell within the dollar range, and because all of the participants were 'members of the movie-going public'. This honorarium was handed out to each participant of all my interviews at exactly the same moment in the proceedings: just before starting the oral consent. Krueger (1994, p. 125) suggested that the assistant moderator should hand them out at the end of the session when thanking everyone for coming, but as I had

stipulated that anyone could leave at any time, I felt it was better that they slip out quietly, rather than interrupting the discussion to ask for theirs before leaving.

Immediately after each focus group I always had a debriefing session with the assistant moderator, where we discussed the points they had made in their detailed notes. As suggested by Kreuger (1994, p. 128), the debriefing captured the first impressions and then highlighted and contrasted findings from earlier focus groups interviews.

Data transcription and analysis

After each focus group, I cut the one-hour plus audio recording into a manageable mp3 file for each part of the discussion. I then listened to each one and transcribed the discussions about the two key questions, the summary, and any other section that I thought might be relevant. For example, the opening questions were only transcribed for the first interview. I transcribed nearly all the one-on-one interview, as this was a conversation rather than a group discussion, and as such, rarely drifted off at a tangent, so most of what was said was worth transcribing.[1]

I exported these transcripts into a qualitative data analysis software package called 'NVivo'.[2] I selected this as it is designed to analyse focus group data, and because I was already familiar with it from when I had analysed my film reviews. After auto-coding the transcripts into NVivo, I had a tree node called 'People' with a branch for each focus group and then a sub-branch for each participant. This meant that by clicking on the name of any participant, I could get a document containing everything they had said during that session without the comments of the other participants. I also created a node called 'Topics' which contained a branch for each section of the questioning structure.[3] By clicking on any of these branches I could get a document that contained the comments from all four transcripts about only the second key question, for example. This made it much easier to analyse and compare the transcripts.

Results and Analysis

Following is a summary of results taken from the transcripts of what the participants of each of the interviews had to say about the four past-future rules and the different

[1] All of the transcriptions can be viewed in Appendix IV, which begins on page 473.

[2] NVivo Version 8 by QSR International Pty Ltd, Doncaster VIC, Australia.

[3] The sections of the questioning structure are listed on page 145 of this chapter.

timelines. Note that the names of all participants were changed to protect their identity as per the confidentiality section of my ethics approval.

1) Focus group interview with the Toastmasters

This took place in the Physics Seminar Room of the Physics Building 38 at The Australian National University at 1.30 pm on 28 October 2008.

To distinguish which past-future rule the participants were using, they were asked to choose between two films with different past-future rules:

- *A Christmas Carol* (2004) with an open future.
- *Slaughterhouse Five* (1972) with a closed future.

During the discussion, I noted which of the different past-future rules the participants ended up choosing. These choices are summarised in Table 5:

Rules	**Glen**	**Neil**	**Mary**	**Rose**	**Tara**	**Bert**	**Judy**	**Total**
Open future	√	√		√	√	√	√	6
Closed future			√					1
Totals	1	1	1	1	1	1	1	7

Table 5: Past-future rules chosen by the Toastmasters' Club focus group

Mary, a counsellor with a degree in social work, initially favoured an open future as she could relate to that in her life, but she went on to say:

> I agree about *Slaughterhouse Five* … I would have to say that I think a lot of things are hard to change – I really know that. On the other hand, I think you can get an epiphany like with Scrooge [the protagonist of *A Christmas Carol*] and you can change your behaviour. You can change your actions, but you may not be able to change your basic personality, but I always say that lately I have been more loving to people … I suppose like Scrooge…

So it appeared she was moving towards the open future; however, she swung back again towards a predestined future when she said:

> I wonder if we have got multiple choices in the present? You have mentioned things that happen that are obviously cause and effect; do we have that much choice really over our present?

Mary concluded that we cannot change the future.

The other six participants all believed that the future was open. Neil, an auditor with a degree in Economics and Accounting, clearly stated that the future "is not all predetermined." Judy had a degree in Literary Criticism and Russian, and she had worked as a librarian and in IT support. At first she said she favoured a rule with a closed future, which she clarified by indicating that time is fixed like in *Slaughterhouse Five* (1972). However, she went on to say, "You can change the future; you are affecting the future" and agreed with Neil when he said that the future is not all predetermined. So she changed her mind by choosing an open future and later confirmed that by saying:

> I don't believe that it [the future] is pre-determined. Our actions affect it. I think we don't have to see the future. I don't believe I can see the future, but I do believe I can change the future by doing things now.

Glen, a business officer with a degree in Management & Economics, agreed with Neil that that the future is not all predetermined, but like Judy thought that *Slaughterhouse Five* (1972) only accurately reflected the fixed nature of the past:

> In *Slaughterhouse Five* you go back to your past, but it doesn't change anything about your present. All you can do is wish you had done something different in the past and wonder about how the present might have changed.

Rose, who was studying Archaeology and Linguistics at an undergraduate level, also believed that the future was open. She commented:

> I think *A Christmas Carol* is really closely related to what our lives are because you can always think back to the past, but you can't change anything. Probably what you do today in the present changes your future.

Tara, an Agricultural Science Lab Assistant, and Bert, an academic in Pharmaceutical Microbiology, both believed that the future was open. They agreed that the future could be changed by learning from decisions made in the past.

To distinguish which timeline the participants were using, they were asked to choose between two films with different timelines:

- *Sliding Doors* (1998) with a parallel timeline.
- *The Butterfly Effect* (2004) with a diverging timeline.

During the discussion, I noted which of the different timelines the participants ending up choosing. These choices are summarised in Table 6.

Timeline	Glen	Neil	Mary	Rose	Tara	Bert	Judy	Total
Parallel	√				√			2
Diverging			√			√		2
Unknown		√		√			√	3
Totals	1	1	1	1	1	1	1	7

Table 6: Timelines chosen by participants of the Toastmasters' Club focus group

Glen was attracted to parallel timelines rather than a new timeline that replaces the old one. Tara agreed because "it is simpler." Glen explained:

> I think there is a variety of bifurcation going on, you know, 'will I do this?' or 'will I do that?' As every minute goes by, there are beginnings of various pathways that we can take. We are not conscious or realising these things, but there is some kind of infinite beginnings, the beginnings of any number of pathways, not just simply two. I must say *The Butterfly Effect* [2004] … from my viewpoint is a little unreal. It seems to me to be retro-adjusting the past to create new pasts … and then you can come back to the present to retro-adjust the past you have just adjusted!

Neither Bert nor Mary believed it was possible to travel back in time, and Bert thought that a parallel timeline could exist "in your imagination, but not in the real world." Although Mary did not believe parallel timelines existed, she said she "would like it to be true." Neil, Rose and Judy did not make a comment during the Ending Questions, so I did not discover which timeline most closely fit their personal model of time.[1]

At the end of the first focus group I asked the group if there was anything that anyone would like to add. The following short discussion ensued:

> Neil: What about the perception that as you grow older, the present goes quicker?
>
> Judy: Yes, it does.
>
> Most others: Yes.
>
> Neil: An interesting phenomenon.
>
> Mary: That is a physiological thing.
>
> Judy: I remember at the age of six, I was given [an advent] calendar and I marked off the days before Xmas and one day took about a year, and now you daren't look at the calendar … Is it because when you are young you are very observant, you observe everything and everything is new and different and now … we are all a bit blasé about it?

[1] In the subsequent interviews, a round robin of all the participants was used for each key question.

> Glen: When you are a small child you are keen to grow up because you see all of these wonderful things that you can do. That's why little kids say, 'I am four and a half, and in January I'll be five!'

Being an older group, the phenomenon of the years seeming to pass more quickly with age was strongly apparent to them.[1] A summary of which member of the focus group chose which model of time is shown in Table 7.

Rule	Parallel timeline	Diverging timeline	Unknown timeline
Open future	Glen, Tara	Bert	Neil, Rose, Judy
Closed future		Mary (inconsistent)	

Table 7: Summary of the models of time chosen by the Toastmasters

Bert, Glen and Tara believed that the future could be changed. Bert thought these changes would create a new diverging timeline that replaced the original one. However, Glen and Tara believed that these changes would create a new timeline in parallel to the original one because it would keep things simpler without any temporal paradoxes. Mary wondered how much choice we really have over our present and she settled on a closed (predetermined) future; however, she later said she believed in a diverging timeline. As this choice had an open future, she had therefore shown an inconsistency in her thinking. Although the other three all thought the future was open, they did not offer an opinion on which type of timeline they believed existed in reality. Also, most of the group strongly agreed with the perception that as you grow older, the present goes quicker.

2) Focus group interview with the physicists

This took place in the Physics Seminar Room of the Physics Building 38 at the Australian National University at 11 am on 30 October 2008.

The participants were asked to choose between four films, each of which used a different past-future rule:

[1] This was discussed on page 68 of the section 'The perception of time' in Chapter Three.

- *Click* (2006) with a closed past and open future.
- *Slaughterhouse Five* (1972) with a closed past and closed future.
- *Back to the Future Part II* (1989) with an open past and open future.
- *Terminator 3: Rise of the Machines* (2003) with an open past and closed future.

Table 8 shows a summary of the results of the verbal survey taken at the end of the discussion about the different past-future rules:

Past-future rule	Will	Eric	Mark	Luke	Paul	Joel	Ross	Nick	Andy	Total
Open-open	√							√		2
Open-closed										0
Closed-open					√		√		√	3
Closed-closed		√	√	√		√				4
Totals	1	1	1	1	1	1	1	1	1	9

Table 8: Past-future rules chosen by participants of the Physics focus group

Will, a PhD student in quantum optics, chose the open past and open future rule. He said this was because he did not like the idea of fate, and because it was the rule that most strongly correlated with the Many Worlds Theory.[1]

Nick already had a physics degree and was studying for a masters degree in Science Communication. He said he thought that we had to assume that our actions had consequences for the future, or we would never take any actions. He thought that the past and future could be changed, but was unsure whether we would ever know if they had been because that would not possible to detect:

> … if you go back into the past and change something, the change you made becomes what had already happened, so you might not even be able to detect it because it would be in the history books that you read as a child that the change you made had already happened.

[1] This interpretation of quantum physics is explained in the section, 'Parallel universes' on page 64 of Chapter Three.

Four of the participants favoured the closed-closed rule. Eric, a PhD student in the area of general relativity, said:

> I believe that if there [were] any time travel, that you would end up forming something like closed time-like curves.[1] The things you are going to go back and change are already part of the past that leads to a future where you go back, so things stabilise, so there is no chance of changing anything that has happened. And I believe that everything that plays out in the future is deterministic, but not predictable, so the interactions that are leading to the future are too many and too varied to ever predict. At the same time, there is no real free choice; no one ever has real free choice.

When I asked, 'if you knew all the variables, could you predict the future?' he replied, "There may be actual real random events in the universe, but I don't believe that anyone can actually direct the future with free will."

Luke, who was doing post-doctoral studies also in the area of general relativity, would not commit at first and would only say, "It depends which philosophical hat you are wearing at the time." Although he did say that in order to remain sane, "You just don't think about it!" However, later in the discussion he said:

> If you are asking personal views, I really feel quite agnostic about what the real essence of time is, but I think I agree with Eric that basically we have very limited free will, if any actual free will …

This aligns with the closed-closed rule. However, he thought that society would go quite badly if people just thought it was all up to fate because then they could do anything they liked. He said, "It would actually basically lead to a very quick death if you didn't think that your own decisions had any consequences."

Joel had a physics degree and was working as an outreach officer in the Department of Physics at ANU. He initially favoured the closed-open rule, but only because it fitted best with his belief in parallel universes:

> I agree with Luke in that I don't have a real strong opinion of whether [the timeline] is fixed or not, but I have some small inkling towards the Many Worlds Theory. In that case, I would say that the future is open. My particular path up to now is not changeable, but there are probably infinite paths that I could have taken in the past and they may exist in other universes, so I would say my own past is not changeable, but it is possible to change the past of a version of me and the future is open.

[1] A closed time-like curve (CTC) is explained in the section, 'Wormholes as time machines' on page 58 of Chapter Three.

He later said that you do not necessarily have to have an open future or past to have free will: you can think of it as you, through your life, are creating your life. However, outside of time, that is what you did in your life and that's fixed.

Mark, a PhD student in general relativity, believed in fate and said, "You can't change anything that will be." Later in the discussion, he went on to explain why he agreed with the closed-closed rule:

> It doesn't make sense that the newspaper would slowly fade to the new timeline. With relativity, I am inclined to take the 'everything is fixed' point of view. In the unlikely event that we can time travel, it might be possible to find out that you are your own grandfather, but not to prevent your conception, not to change anything … The whole free will thing: I don't think that is such a problem because you don't know what the future is going to be, so it doesn't really matter if you are pre-destined to live it, which is kind of like an attitude Christians have had for a long time: that God predestines everything, but that doesn't mean that you don't have to behave in a good way.

Three participants believed in a model of time with the closed past and an open future. Paul, an honours student studying general relativity, reasoned:

> I would say that I believe the future is open in terms of cause and effect. What I do now will affect what happens later on, but there is nothing saying that I have to do something now, such that something happens later on … I suppose the future is open and it all branches out, so from any instant in time there are so many different futures depending on what you choose to do at that time. So, I suppose I like the idea of a certain amount of free will – that you aren't just railroaded into a definite future. But as to changing the past … I agree with what you were saying that if you do go back and change the past, you change what has already happened, so therefore you haven't changed anything. If you could take a totally external view, you probably have changed something, but as far as anybody else is concerned, you have done nothing. So in practice you can't [change the past].

Ross, a software engineer with a physics degree, believed that the timeline really worked in the same way that we experience it, even if parallel worlds exist:

> So even though there might have been different timelines branching out everywhere, in terms of what we are experiencing, it feels like we have a fixed past, but a changeable future, just because that future is the one we are experiencing and that is the timeline we are on.

Andy, a software engineer with a degree in physics and civil engineering, agreed with the closed past, open future rule; but he wanted to qualify it in two ways:

> One is [that] our perceptions of what happened in the past aren't necessarily what actually happened because we systematically re-write history and often actions now are based on what you thought happened, not what actually

> happened. The second one is the future, again, I think that we are to some extent locked in because past actions have future consequences, and so although in theory free will gives you room to move; in fact your free will is quite limited because of past events and actions. My feeling of free will is that you only have a limited range of choices within where you are at, who you are … so that it is not open; it is just highly constrained simply because of what sort of beast you are.

The participants were then asked to choose between three films with different timelines:

- *Sliding Doors* (1998) with a parallel timeline
- *The Butterfly Effect* (2004) with a diverging timeline
- *Terminator 3: Rise of the Machines* (2003) with a converging timeline

The following film was then introduced later in the discussion as another option:

- *Déjà Vu* (2006) with a double well timeline

If the participants did not like any of these options, they were allowed to choose another type of timeline. One participant chose a fixed timeline that never changes.

Table 9 shows a summary of the results of the verbal survey taken at the end of the discussion about the different timelines:

Timeline	Will	Eric	Mark	Luke	Paul	Joel	Ross	Nick	Andy	Total
Parallel	√	√	√			√	√	√		6
Diverging					√					1
Converging									√	1
Double well										0
Fixed				√						1
Totals	1	1	1	1	1	1	1	1	1	9

Table 9: Timelines chosen by participants of the physics focus group

As can be seen, six out of nine of the physics focus group believed in parallel universes. Joel said that the diverging timeline used in *The Butterfly Effect* (2004) does not seem to make sense as changing one timeline just means that it is the same timeline anyway, and it is not changed because it is what you did anyway. He strongly believes that if you could go back in time, you would be creating another timeline, like the Many Worlds

Theory, where when you make a decision the universe splits and you live in both universes. He explained:

> I was thinking that if there are parallel universes, then you must really assume that there is an infinite possibility of happenings at every moment. The universe splits into every single possibility at every moment in time. So, if you did travel back in time, then that would already be encompassed because that is one of the timelines that would already exist … So it is not that you are going back in time and changing the timeline – you are going back, which is what you are destined to do to enter that universe anyway.

Ross and Will preferred the parallel timeline and Will agreed with Joel that if travel into the past was possible, another timeline would be created in parallel because things have to split up. Mark eventually opted for a model of time with parallel timelines, but only after considering the following:

> I don't know how [a closed past with a closed future] fits with the Many Worlds Theory. Presumably something like this: a foliation[1] and there are heaps of such different timelines, but they all have that property of nothing changing, so there is no inconsistency in any of the possible future timelines … it seems like [parallel timelines are] better in that both trouser legs are experienced, rather than being able to choose which one you would rather experience, which is more what [the diverging timeline] seems to be.

Eric pointed out that the Many Worlds Theory does not play very strongly into any discussion on time because each world has a fixed single timeline. He said:

> I can't rule out the *Sliding Doors* kind of possibility of alternate timelines existing, but then you have to look at each individual one. I believe each individual one is in itself a fixed single timeline. If you could go backwards and actually have time travel, everything would stabilise in the sense that everything you did in the past would lead to the future… That would be self-consistent, not changing like you had in *The Butterfly Effect*. You couldn't just completely alter the timeline and somehow have memory of everything … all of that ends up relying on some sort of sense of being outside of the timeline when it changes…

Although Nick believed in parallel timelines, he thought some might converge again:

> There might be another place where those things diverge again, which could make a huge difference, but most divergences won't… I think it comes down to a question of what you can detect. If it is a single timeline and you go back and change it, I don't think you can ever detect that because it is what was there all along. So if it is a multiple timeline, if you can go back and make a change and that causes the universe to split, then the only way you would know is if your memories are different from everybody else's, which suggests you have gone back down one leg of the trousers and gone forward up the other one.

[1] A geological term referring to the arrangement of leaf-like layers in a rock.

He said you would never see a photograph changing; it would always have just been the photograph. You may have a memory of how the photo was, but if it was a single timeline, you could never detect it. He explained that if you possess the photo that has travelled back with you, then the photo would be the same as your memory. So if you could detect it, then there must have been multiple timelines. He went on to say that by assuming the parallel timelines idea, when you go back and change something, then both outcomes must have existed anyway, so you have not actually changed anything. He said, "Your perception is that you have gone back down one channel and up the other, but in the greater scheme of things, you haven't changed anything, as they both already existed!" He then said that you would not go back in time to change the past in order to change the present, rather you would go back to experience a different timeline.

Luke thought that parallel worlds were just an unproven belief:

> That is the thing about Many Worlds is that you can't prove or disprove it, so it is just a philosophical viewpoint. So what you can conceive of may be possible, or may not, but in terms of possibility, we have no way of measuring it, so we don't really know what is possible.

Luke strongly believed in a closed past, closed future rule, and did not believe in parallel timelines, so his only option was a fixed timeline.

Paul did not agree with parallel worlds, and initially said that he honestly did not know:

> When you go back, you change something … if it immediately [splits], then in that case you would still have an idea that you have changed something … no, that kind of contradicts what I said before, so I reckon no, you can't change it, it won't [split]. So I suppose that is the [diverging timeline] option.

He did mention that if he bought a lottery ticket and lost, he would like to go back and try to find the parallel branch where he had won, so it seems he would like to believe in parallel worlds, but could not do so because it conflicted with what he had said before.

Andy differed from everybody else by going for a converging timeline, but said that he did not think that we have any evidence for any timeline:

> I am uncomfortable with the parallel universes one because there are going to be too many of them. I am uncomfortable with going back and changing something because that doesn't fit with my fixed past [rule] … A science fiction story that I read ages ago … which is about somebody going back, trying to change events, and he can't as this whole thing is happening, which prevents any change, so it is a molasses sort of effect.

This story is an example of the Novikov self-consistency conjecture.[1]

Chaos theory was not discussed in the first focus group interview; however, I introduced it to this group as a separate discussion towards the end of the interview. I mentioned how in the film *Déjà Vu* (2006) a different future was only be possible if a significant enough change was made to the past, and asked them if they thought this type of timeline would exist in their personal model of time. They were all familiar with chaos theory and the butterfly effect, but none of them thought a double well timeline was an accurate description of their personal model of time. Following are some of their comments:

> Nick: In the general idea of the Butterfly Effect, they say a tiny change can change everything, but most of them don't. There is one tiny change every now and then that has a huge effect, so you could go back and you could live your entire life in the past and not muck about with anything significant.
>
> Joel: There is a probability based on the amount of the effect you have, so if you do something tiny, then there is a small probability that it changes things.
>
> Nick: If you do something tiny at just the right point, but the chances of you doing something at just the right point are actually quite small.
>
> Luke**:** Yes, the right conditions.
>
> Nick: You would have to wait for the right butterfly to pass.
>
> Luke**:** I think as Nick pointed out, you really need the right conditions [for it] to be chaotic … For example, as humans, we only have only a certain amount of capacity for energy, so we can't push mountains aside and things like that. So conditions really need to be set up in an unstable equilibrium basically. So we need a marble at the top of the hill.
>
> Joel: You mention being at the right time because the change you need to make varies in time as well. So at some point in time, there might be a tiny little change that you need to make, and at some point, it gets bigger and bigger the change that you need to make.

Table 10 shows a summary of the results of the verbal survey taken at the end of the discussion about the different models of time.

[1] As previously discussed in the section, 'Novikov self-consistency conjecture' on page 64 of Chapter Three.

Past-future rule	Parallel timeline	Diverging timeline	Converging timeline	Double well timeline
Open-open	Will, Nick			
Open-closed				
Closed-open	Ross	Paul	Andy	
Closed-closed	Eric, Mark, Luke, Joel			

Table 10: Summary of the models of time chosen by the physicists

One of the most common interpretations of the theory of relativity is the block universe, which has both the past and future closed, and four out of the nine physicists believed that we have very limited free will, if any actual free will. Eric said that although the future is deterministic, it is not predictable. Joel pointed out that you do not necessarily have to have an open future or past to have free will: you can think of it as you, through your life, are creating your life; however, outside of time, that is what you did in your life and that's fixed. Nick thought that if the past were open, it would be hard to detect any changes you made because they would become what had already happened. On the other hand, three of the physicists believed that time worked in the same way that the mind experiences it: with a closed past and open future.

The existence of parallel universes is also a theory in physics, and six out of the nine physicists confirmed that they believed in parallel timelines. Nick pointed out that if parallel timelines existed, you could not go back and change the past, you could only go back to experience a different timeline in the past. Luke was not convinced about parallel timelines and pointed out that because you cannot prove or disprove them, they are just a philosophical viewpoint. Eric did not like how the time traveller could somehow still have a memory of everything on the original timeline when the diverging timeline had replaced it. He felt that it was relying on some sense of being outside of the timeline when it changed, which is why he preferred parallel timelines.

The participants were all familiar with chaos theory and the butterfly effect, but none of them thought a double well timeline represented their personal model of time.

All the physicists were careful to choose timelines that were consistent with the past-future rule that they had previously chosen: For example, Mark managed to reconcile his choice of parallel timelines with a closed past and future by specifying that all the

future parallel timelines must have the property of nothing changing, so that they all remained consistent. Also, they all chose a model of time that yielded a self-consistent universe without paradoxes. Being physicists, this was an important criterion for them.

3) The Dunedin interviews

The following are a combination of results from both the focus group interview and the one-on-one interview that took place in Dunedin.

The participants were asked to choose between four films, each of which used a different past-future rule:

- *Click* (2006) with a closed past and open future
- *Slaughterhouse Five* (1972) with a closed past and closed future
- *Back to the Future Part II* (1989) with an open past and open future
- *Terminator 3: Rise of the Machines* (2003) with an open past and closed future

Table 11 shows a summary of the results of the verbal survey taken at the end of the discussion about the different past-future rules:

Past-future rule	Sean	Gary	Hans	Beth	Phil	Alan	Ruby	Lisa	Jose	Total
Open-open	√				√		√			3
Open-closed										0
Closed-open		√	√	√		√		√	√	6
Closed-closed										0
Totals	1	1	1	1	1	1	1	1	1	9

Table 11: Past-future rules chosen by the Dunedin participants

Six of the nine participants opted for the closed past, open future rule. Alan, who had a biology degree and was doing a masters degree in science communication, commented:

> I think things that have already happened, you can't change; where it is nice to think that things that are going to happen in the future you have got some influence over, otherwise what is the point of making decisions now if things that are going to happen are going to happen?

Beth, a teaching fellow in anatomy with a biology degree, felt that changing your opinion of the past could affect your future. She said:

> I guess it is like learning from the past … you may glean some information that sheds a different light that ends up changing the whole situation for you … it is just a feeling I have. I think there are some things that through changing your own opinion maybe will alter your choices in the future.

Gary worked in IT support for the Zoology Department and had a computer science degree, and Lisa, who had a degree in Media Studies & Film, both opted for the closed past, open future rule. She liked the idea that your perception could change, and thought the future was wide open, that anything could happen; it just depended on how you played it. He said:

> It is just that because if it is open-open and you go back and change it, then the present that is supposed to be the future of the past wouldn't be happening. It is just getting a bit confusing … if you have regrets in the present and you decide to go to the past, if you can, and change it, then the regrets won't be there and therefore you wouldn't go back to change it – it is an infinite loop going on … by going back, then you change your past, then supposedly, you won't be going back.

Neither Hans, a lawyer with a political science degree, nor Jose, a zoology lab technician, had a strong opinion about the different past-future rules, but in the end they both also said they believed in the closed past, open future rule.

The remaining three participants favoured an open past, open future rule. Phil, a research assistant in the Zoology Department with a biology degree argued that:

> If everything is predetermined, then you might as well say that nothing out there now is going to affect anything in the future because nothing I have done in the past has affected the future … So if you were to go back now, it would be like being in the present, but in the past. So by saying it would have no impact is like saying that anything I do now would have no impact.

He also said that changing the open past relies on you being able to participate when there, as opposed to only being able to look at the past. Ruby, who worked in marketing and had a chemistry degree, said that an open past, open future was how she wanted it to be:

> I don't know why … but I think that the future has got to be open … I think that if you are in control of this moment now, and you were to go back, you would be in control of that moment, so it has to be open.

The one-on-one interview was with Sean, who had worked in various roles in film, TV and radio and was currently teaching a short film course at a local high school. He said that he found it very interesting that the juxtaposition of time was like a "corridor" (closed path), but also entirely "plastic" (bendable). He went on to say:

> If time is a corridor and this moment of 'now' is a compressed lens of existence (this moment that we share here and now) which by definition is repeatable because it is being recorded, I think that the future and the past are both open and the single (I hate this phrase) 'nowness', this instant moment is only concrete while we are able to perceive it.

He liked *Terminator 3: Rise of the Machines* (2003) because it gave a finite resolution; however, he preferred the open past, open future rule as it most closely represented his personal model of time.

Timelines

The participants were asked to choose between four films with different timelines:

- *Sliding Doors* (1998) with a parallel timeline
- *The Butterfly Effect* (2004) with a diverging timeline
- *Terminator 3: Rise of the Machines* (2003) with a converging timeline.
- *Déjà Vu* (2006) with a double well timeline

The option of a fixed timeline was not brought up as nobody had chosen a closed-closed rule. Table 12 shows a summary of the results of the verbal survey taken at the end of the discussion about the different timelines.

Timeline	Sean	Gary	Hans	Beth	Phil	Alan	Ruby	Lisa	Jose	Total
Parallel		√					√		√	3
Diverging	√				√	√		√		4
Converging										0
Double well			√	√						2
Fixed										0
Totals	1	1	1	1	1	1	1	1	1	9

Table 12: Timelines chosen by the Dunedin participants

Beth said she believed in the converging timeline, which she described as "all roads lead to Rome." She liked the idea of having a destiny, but being able to go back and change the way she got there, so she could have more fun along the way. However, she wanted to include significant change as one of the options, which meant she could change her destiny by deliberately trying to change something significant, which really means that she was going for the double well timeline.

Hans also opted for the double well timeline: "The big change where something will always happen, well mostly, if you make a big enough change … It depends on how big the event you are talking about is." He did not like the diverging timeline because as soon as you go back in time, the timeline must converge back to that point, or you might never have come back. He says, "So it makes you wonder why they go back!"

Note: Both Hans and Beth earlier chose the closed past, open future rule, which would contradict the double well timeline unless they could only change their destiny from their present point in time onwards.

Four of the nine believed in a diverging timeline. Phil chose it because he liked the idea that if he went back in time and walked left out of a door instead of right, it could change something significant in the future. This fitted in with his choice of the open-open rule. Alan also believed in a diverging timeline, but only from his present point onwards, meaning that he believed in a single timeline with no backwards time travel, which agrees with his choice of the closed-open timeline. He said:

> If you believe in [a converging timeline], it almost makes you think that you can't affect things in your own life … I like that idea that changing something small could have knock on effects in the future and the future could be completely different.

Lisa also believed that the past could not be changed, and that the timeline could only diverge from her present point onwards. She said, "Very small currents can actually have a very big impact ultimately." This was consistent with her choice of the closed-open rule. Sean said that he was interested how a single insignificant event in *Sliding Doors* (1998) completely altered the corridor of time. However, he did not believe that both worlds could co-exist, so he opted for a diverging timeline like the one in *The Butterfly Effect* (2004). He said as a filmmaker, he would want to engage them all, but concluded:

> I am going for the [diverging timeline] and I am actually surprised that that would be my choice … There are so many things within my life where I would definitely make changes, which would put me in a completely different place, which means that I would never be having this conversation with you!

Three of the nine believed in a parallel timeline. Ruby found it quite hard to believe that there could be another version of her, but concluded that she preferred the idea of a parallel timeline. However, she could not see hopping between them as an option. She thought that you would only be able to travel backwards and forwards from where you were. This fits in with her choice of the open-open rule.

Gary went with parallel timelines because "you can have infinite possibilities at any given time." However, this was from this point onwards, as he did not believe in being able to go back and change the past, which fitted in with his choice of the closed-open rule.

Jose believed in parallel worlds, but he said that for more significant worldly occurrences they could converge to arrive at the same outcome. So when he chose the closed-open rule, what he meant was that time travel into the past was not possible, we were stuck with this world, but that we can choose any one of the possible parallel timelines for the future, but certain things like another world war, may be in all of the futures.

Summary

A summary of the results of the verbal survey taken at the end of the discussion about the different models of time is shown in Table 13.

Past-future rule	**Parallel timeline**	**Diverging timeline**	**Converging timeline**	**Double well timeline**
Open-open	Ruby	Sean, Phil		
Open-closed				
Closed-open	Gary, Jose	Alan, Lisa		Hans, Beth (inconsistent)
Closed-closed				

Table 13: Summary of the models of time chosen by all the participants in Dunedin

Six of the nine participants from Dunedin believed that this most closely represented their personal model of time. Phil and Alan decided the future had to be open; otherwise there would be no point in making decisions in the present. Phil thought that if you went back to a closed past, you would find yourself unable to participate in it. Beth thought you could still learn from the past while there, and that could change your whole future. Gary also thought that the past was fixed because if you went back to fix a regret, then there would be no regret for you to go back for, which would create a temporal paradox.

Sean, Phil and Ruby all thought that the past could be changed as well as the future. Sean and Phil thought that the new timeline would replace the original one and diverge away from it, whereas Ruby thought the new timeline would exist in parallel to the original one. She reasoned that if you were in control of the present moment, and you went back in time you would then be in control of that moment, so the past has to be open. Hans and Beth liked the double well timeline even though this contradicted their previous choice of a model of time with a closed past.

Discussion of Results

The first focus group interview (with the Toastmasters) did not discuss all four past-future rules because only two of them had been developed at that stage. Neither was it able to discuss all five timelines because only two of them had been developed at that stage. Therefore, the results from this focus group could not be directly compared with the following three interviews where the participants were given four past-future rules and five types of timeline to choose from.

Past-future rules

The first purpose for conducting the interviews was to discover which of the past-future rules that I had discovered in Chapter Four were present in the personal models of time of the movie-going public. The results in Figure 47 verify that three of the four rules were present and that one was missing.

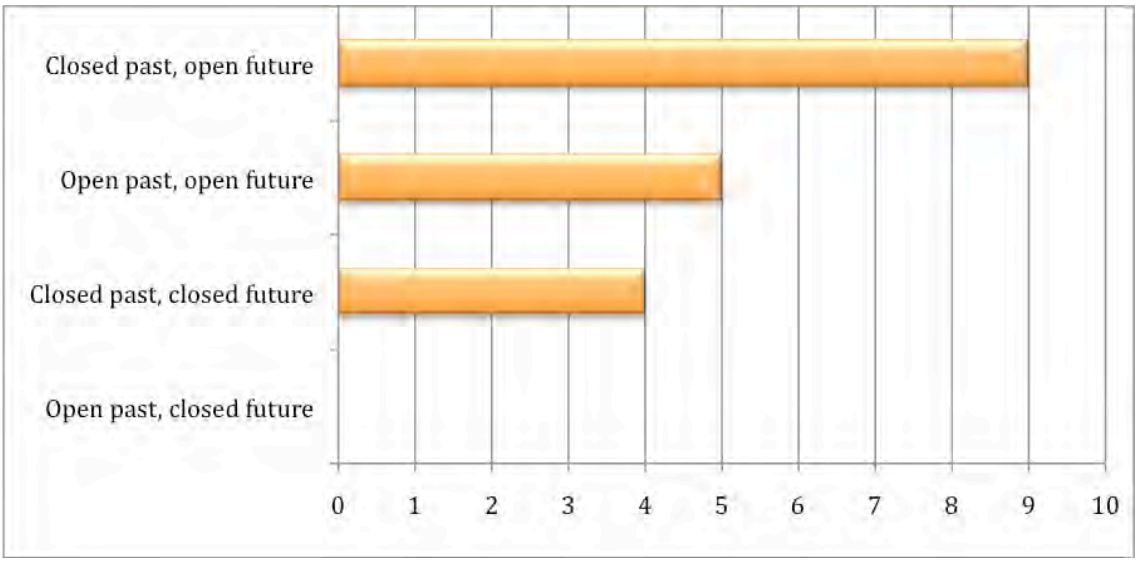


Figure 47: Number of participants who chose each of the past-future rules

This graph is not necessarily representative of the wider movie-going public because half of the participants have an academic training in the physics of time, and because the sample size is too small. What it does show is that at least some of the movie-going public believe that three of the four rules represent how time works in reality. In addition to theses results, six members of the first focus group interview believed that the future was open, which would have increased the numbers of the first or second rule (or both) in Figure 47. The other member of this focus group believed that the future and past were both closed, which would have added to the total of the third rule in Figure 47.

It is therefore clear that like the other interviews, nobody from the first focus group interview believed that the open-closed rule was present in their personal model of time. This is the rule where it does not matter how much you change the past because only one future can exist as represented by the films, *Groundhog Day* (1993) and *Terminator 3: Rise of the Machines* (2003).

Half of the participants believed that a closed past with an open future most closely represented their personal model of time, even though it goes against the block universe (past and future closed), which is the most common interpretations of the theory of relativity. It is hard to justify having one rule for the past and another for the future when there is no universal ‘now’ moment to separate them. The rest of the participants were split between time being completely open and time being completely closed.

Figure 48 compares the different past-future rules chosen by the participants who had a physics background compared to those who did not.

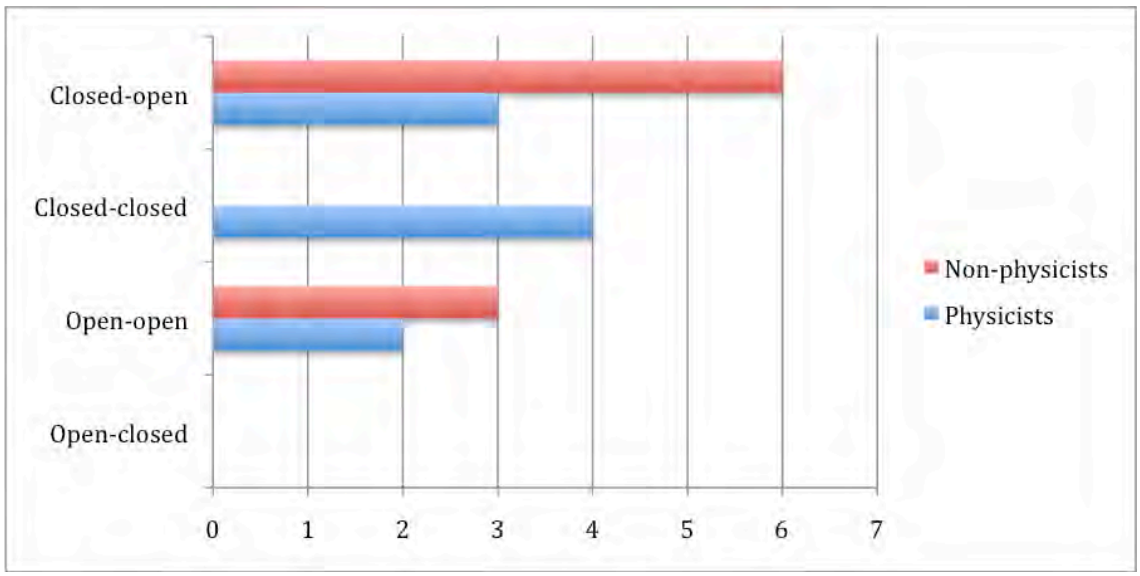


Figure 48: Number of physicists and non-physicists who chose each of the past-future rules

Most of the non-physicists believed that the past was closed and the future open, which is the way the mind experiences time; however, some did think that the past could be open as well as the future. This may have been because there were several people in this focus group with a film background, and as previously shown the most common past-future rule used in films is the one with an open past and open future. Because they were unwilling to consider a closed future, the choices of the non-physicists were polarised between the two rules with an open future. All of the Toastmasters' focus group also believed in an open future except for one participant, who believed that the past and future were both closed. The results of the physicists on the other hand were more evenly spread across the three rules. Like the non-physicists, none of them believed in a model of time with an open past and a closed future.

Figure 49 compares how much difference having a physics background made to the participants' beliefs about the past.

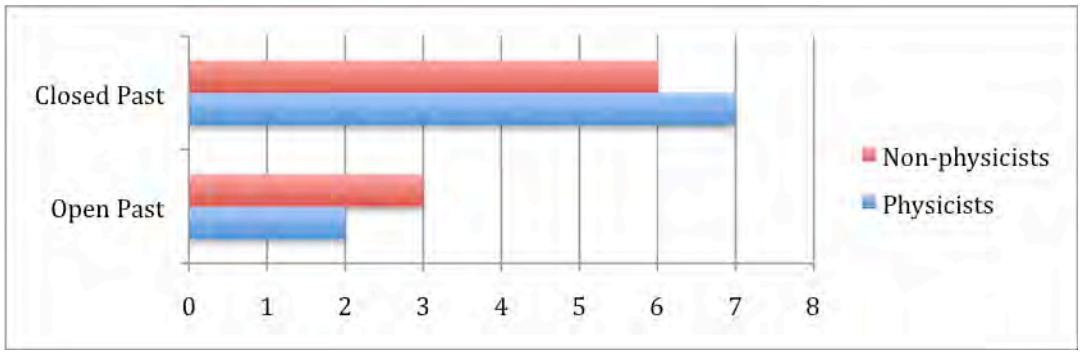


Figure 49: A comparison between the number of physicists and non-physicists who believed the past to be open or closed

It is interesting to note how similar the physicists' beliefs about the past were compared to the non-physicists. The majority of both groups believed that the past is closed. However, the same cannot be concluded when I compared how much difference having a physics background made to the participants' belief about the future, as shown in Figure 50. Note that data could be included from the Toastmasters' focus group in this chart, because its participants were all asked about whether they believed the future to be open or closed.

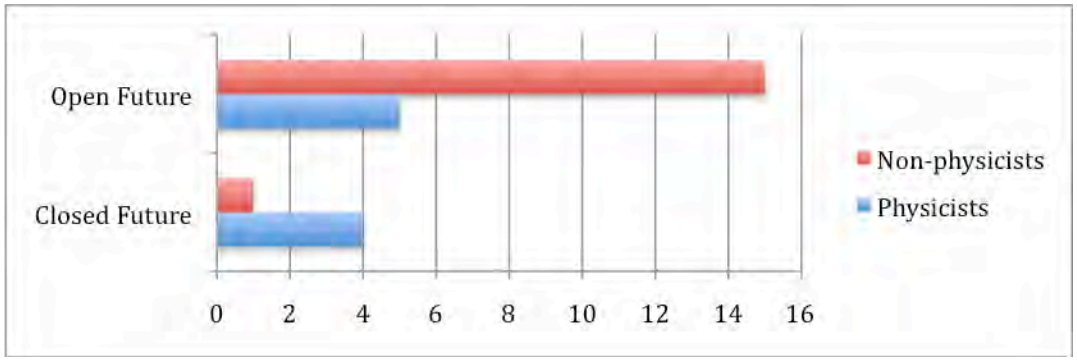


Figure 50: A comparison between the number of physicists and non-physicists who believed the future to be open or closed

The non-physicists showed a strong preference for an open future rule, probably because this is how the mind experiences time. About half of the physicists agreed, but the other half believed that the future was closed which is in alignment with the block universe - the most common interpretation of the theory of relativity. It was interesting to observe how they were torn between their personal experience of time and a proven scientific theory of time. One physicist was keen to point out that if the future is predestined, this does not mean that it is totally predictable.

Timelines

The second purpose for conducting the interviews was to discover how many of the five timelines I had discovered in Chapter Four were present in the personal models of time used by the movie-going public. The results in Figure 51 show that each of the five timelines was present for at least one participant.

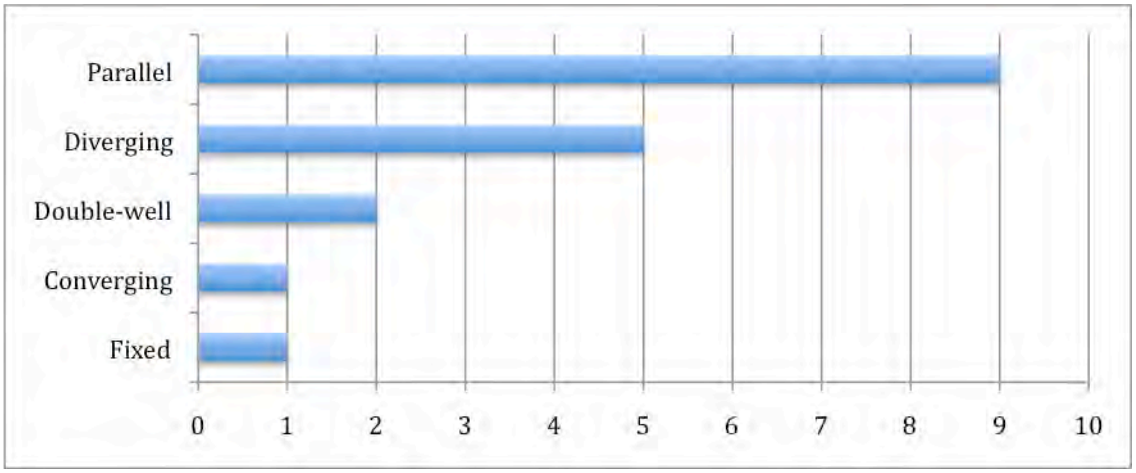


Figure 51: Number of participants who chose each of the five timelines

Only one participant thought the timeline was completely fixed, and the most popular timeline of the verbal survey was the parallel timeline. However, as the diverging, converging and double well timelines are all subsets of a replacement timeline, they can be combined so that the five types of timeline can now be reduced to three general types of timeline. Figure 52 shows how the popularity of these three general types of timeline are spread across the three focus groups.

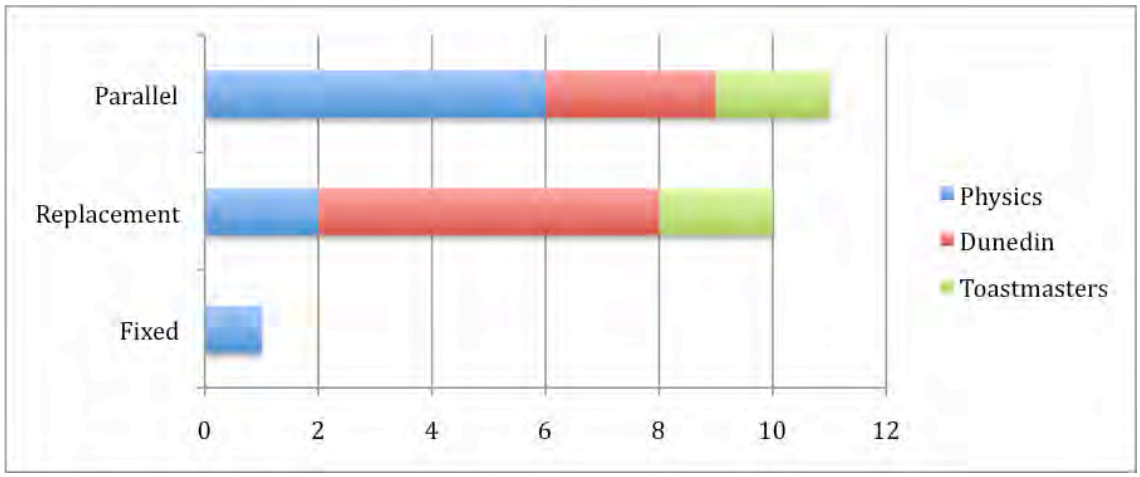


Figure 52: Number of participants who chose a parallel or replacement type of timeline

It can be concluded that overall there is little difference in preference between a parallel timeline and a replacement timeline. However, it does appear that there was a tendency for participants with a physics background to make different choices compared those who had none, as show in Figure 53.

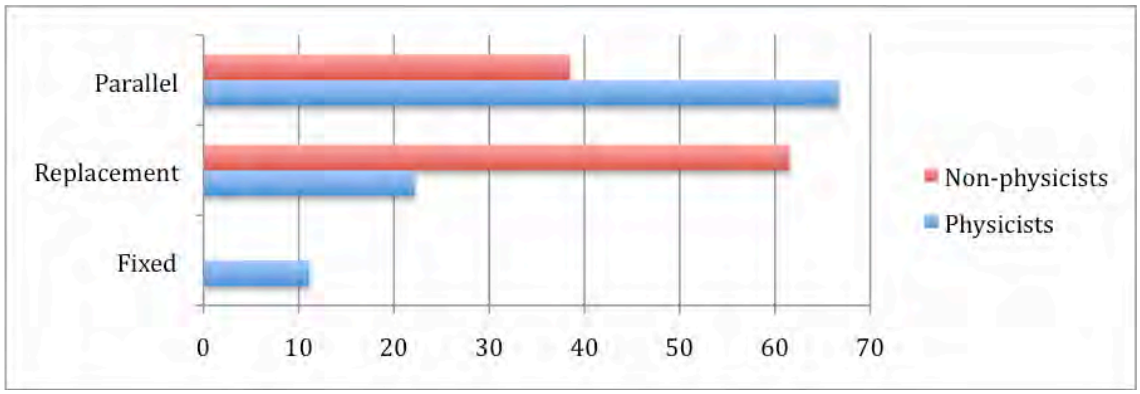


Figure 53: Percentage of physicists compared to non-physicists who chose the different types of timeline

I expected more physicists than non-physicists to choose parallel timelines because the 'Many Worlds Theory' is a possible interpretation of quantum physics. Figure 53 shows that the majority of physicists believed in parallel timelines. Those that did not choose them thought that although they were theoretically possible, they were more of a philosophical standpoint because their existence could never be proved. About a third of the non-physicists believed in parallel timelines, which was more than I was expecting. The majority of the non-physicists believed in the type of replacement timeline where the original timeline collapses and is replaced by a new one, and whose events begin to diverge away from the original ones.

Combining past-future rules with timelines

The past-future rule and the general type of timeline that each participant chose can then be combined to reveal the model of time for each participant as shown in Table 14.

Participant	Open-open	Open-closed	Closed-open	Closed-closed	Parallel timeline	Replacement timeline	Fixed timeline
Will	√				√		
Eric				√	√		
Mark				√	√		
Luke				√			√
Paul			√			√	
Joel				√	√		
Ross			√		√		
Nick	√				√		
Andy			√			√	
Sean	√					√	
Gary			√		√		
Hans			√			√	
Beth			√			√	
Phil	√					√	
Alan			√			√	
Ruby	√				√		
Lisa			√			√	
Jose			√		√		

Table 14: The model of time chosen by each participant

Table 15 is a matrix of the four past-future rules and the three general types of timeline. This reveals the number of participants that chose each of the models of time.

Past-future rule	Parallel timeline	Replacement timeline	Fixed timeline
Open-open	3	2	Not possible
Open-closed	0	0	Not possible
Closed-open	3	6	Not possible
Closed-closed	3	Not possible	1

Table 15: The number of participants that chose each model of time

In Table 15 there were three participants who believed that a parallel timeline could be created with a closed past and a closed future. Up until this point, I had dismissed this

model of time as an impossible combination; however, upon deeper reflection it seems that a new model of time had emerged from the analysis of the interview data.[1]

Out of the eight possible models of time in Table 15, six were found to be valid for at least some member of the moving going public, and two were not chosen by any participants: they both involved an open past with a fixed future. This is the past-future rule used in the films, *Groundhog Day* (1993) and *Terminator 3: Rise of the Machines* (2003). Although films like these are self-consistent and may be interesting to watch, none of the participants had a personal model of time where there could be different versions of the past but only one version of the future.

Comparing the focus group interviews

There was no noticeable difference between the focus groups regarding the number of participants. Everybody knew each other in the first two groups, or at least had seen the other people before, either around the Physics Department, or at Toastmasters Meetings. The Dunedin group was the quietest and took the least time to complete. It took a lot longer to get this group talking, but by the end of the session the group was really warmed up. The participants seemed much more comfortable talking about the perception of time, rather than the physics of time, which may have been because many had a biology or film background. When the conversation at the end switched to the neurology of the brain, they all became quite vocal.

The members of the first focus group (Toastmasters), except for one, were all aged over 50. The members of the second focus group (Physicists), except for one, were all aged under 30, and all of those interviewed in Dunedin were all aged between 30 and 50. The difference in the average age of the groups did not make any noticeable difference, except that the Toastmasters were the only group to mention that time now appeared to be moving faster for them than when they were younger.[2]

Summary

25 members of the movie-going public were interviewed in total, all of whom had to have previously watched some time travel films. A verbal survey was carried out with

[1] This new model of time is discussed more fully in the section ‘Timeline types’ on page 182 in Chapter Six.

[2] This phenomenon was discussed in the section ‘The perception of time’ on page 68 of Chapter Three.

18 of them. These numbers are not representative of the movie-going public, but do show which of the past-future rules and timelines are valid for at least some of the movie-going public.

Past-future rules

Three of the following four following past-future rules that I discovered in Chapter Four were held as a valid belief by some of the movie-going public:

1.	Closed Past	Open Future	9 participants
2.	Open Past	Open Future	5 participants
3.	Closed Past	Closed Future	4 participants
4.	Open Past	Closed Future	0 participants

There seemed to be a stronger preference for the closed-open rule, which is how the human mind usually experience time even though this contravenes the block universe, which is the most common interpretation of Einstein's theories of relativity.

Types of timeline

The results of this study found that all of the five types of timeline discovered in the Chapter Four were held as a valid belief by some of the movie-going public:

1.	Parallel timeline	9 participants
2.	Diverging timeline (replacement)	5 participants
3.	Double well timeline (replacement)	2 participants
4.	Converging timeline (replacement)	1 participant
5.	Fixed timeline	1 participant

When the five types of timeline were then reduced to three general types of timeline, it could be seen that there was a much stronger preference for the parallel and replacement timelines than for the fixed timeline.

1.	Parallel timeline	9 participants
2.	Replacement timeline	8 participants
3.	Fixed timeline	1 participant

Comparing the physicists with non-physicists

All of the non-physicists believed in a past-future rule with an open future, which is compatible with how the human mind experiences time, whereas about half of the physicists believed in a closed-closed rule, which is compatible with the block universe - the most common interpretation of the theory of relativity.

The majority of the non-physicists chose replacement timelines, which are very common in films. The majority of physicists chose parallel timelines, which are a possible interpretation of quantum physics, and allow for a self-consistent universe, which was an important concept for many physicists. They commented that when watching a time travel film, they were prepared to suspend their beliefs about the nature of time, on the condition that the plot was self-consistent within the adopted model of time.

Models of time

By combining the answers from both key questions, a model of time for each participant was formed. Six out of the eight possible models of time were found to be valid for at least some members of the moving going public.

Although the study using interviews was only exploratory, it provided some interesting insights, such as the perception that the present goes quicker as you grow older. It also allowed me to judge which of my models of time were being used by at least some members of the movie-going public; and a new model of time emerged that I had previously considered impossible.

In the following chapter, I will synthesise the findings of the film study in Chapter Four with the findings of the interviews in Chapter Five. I will then compare them with the theory from Chapter Three to help construct a comprehensive set of models of time that help to clarify thinking about the nature of time.

CHAPTER SIX: SYNTHESIS

> *The future has not been written. There is no fate but what we make for ourselves. I wish I could believe that.*
>
> – Nick Stahl, actor[1]

The aims of this chapter are as follows:

- To compare the results of the film study with those of the interviews.
- To analyse these results in order to develop the past-future rules and the timelines.
- To compare these findings to the theories and ideas in Chapter Three in order to fully develop the past-future rules and the timelines.
- To test these fully developed past-future rules and the timelines against the full data set of films.
- To combine the fully developed past-future rules and timelines to construct a comprehensive set of models of time.
- To create a method for determining a person's personal model of time travel.

I begin by comparing the film results from Chapter Four and the focus group results of Chapter Five. In the analysis that follows, I introduce the concept of timeline properties, which develops a more accurate structure for the timelines, and leads to a comparison with the theory from Chapter Three.

Comparison of the Film and Interview Results

In the following section, the film results from Chapter Four and the interview results from Chapter Five are compared for the different past-future rules and for the different types of timelines.

[1] Voiceover of John Connor, the lead character in *Terminator 3: Rise of the Machines* (2003).

Past-future rules

Figure 54 shows what percentage of films from Chapter Four used each of the four past-future rules, and what percentage of focus group participants thought their personal model of time corresponded to each rule.[1]

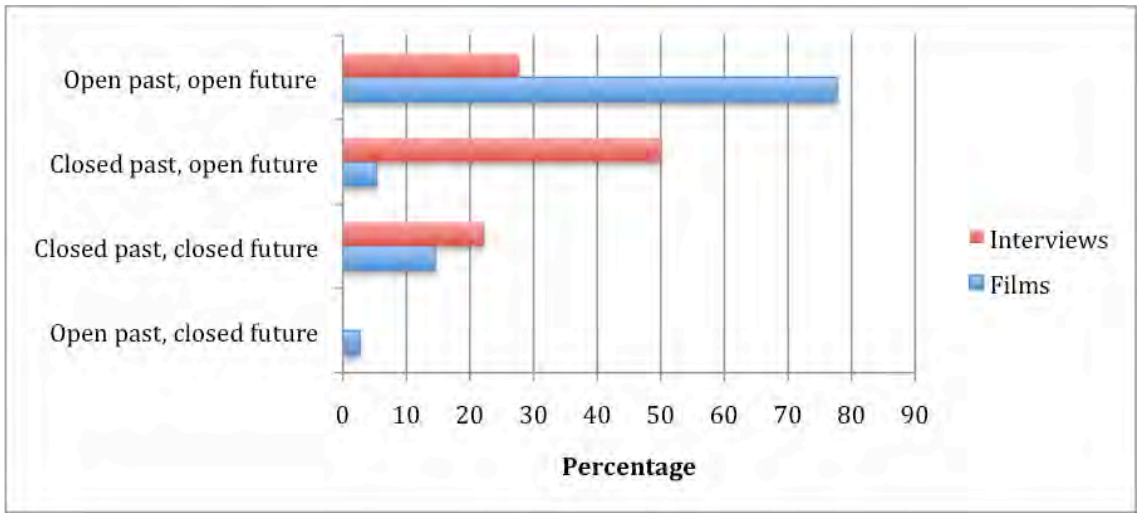


Figure 54: Comparison of past-future rules as a percentage

The filmmakers had a strong preference for using the rule with an open past and open future. This rule allows for greater creativity causing a richer variety of plots, however it also allows for inconsistencies and temporal paradoxes, which are often conveniently ignored. The participants of the interviews, however, were split more evenly between the first three past-future rules, with the most popular being the closed past, open future rule.

Timelines

By the end of Chapter Four, I had identified five types of timeline: the converging, diverging, double well, parallel, and fixed timelines. Unlike the fixed and parallel timelines, the other three timelines (diverging, converging and double well) all replace the original timeline, so for comparison purposes they will now be known as replacement timelines. This leaves three general types of timeline:

[1] In the first focus group interview, only future rules were discussed, so only the results from the subsequent interviews could be included in this comparison of past-future rules.

- Replacement timeline (converging, diverging or double well timeline)
- Parallel timeline
- Fixed timeline

Figure 55 shows how many films in my data set used the three different types of timeline, and also which one the participants of the interviews believed to be closest to their personal model of time.

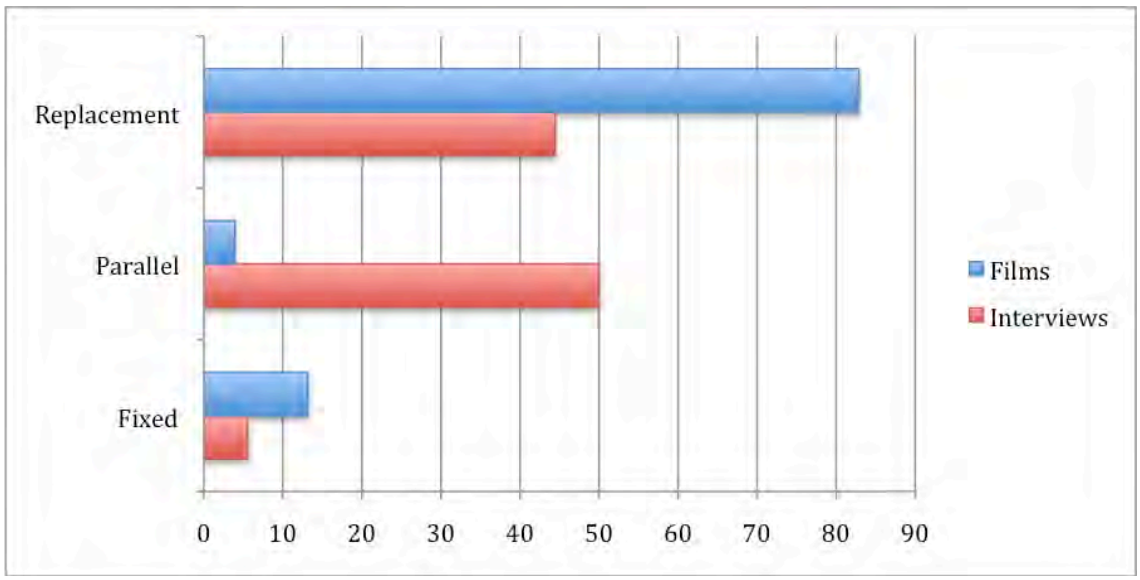


Figure 55: Comparison of timelines as a percentage

Filmmakers had a strong preference for using the replacement timeline, which is likely to be for the same reasons as their preference for the open-open rule, as discussed in the previous section. Like the open-open rule, inconsistencies and temporal paradoxes often occur in this type of timeline. The interviewees showed little difference in preference between the replacement and parallel timelines. The fixed timeline was popular neither with filmmakers nor participants of the interviews, which was to be expected as rather than all events on the timeline being fixed, many people in our Western culture are attached to the idea that they have free will and choice.[1]

[1] This concept was discussed in the section, 'Free will and determinism' on page 46 of Chapter Three.

Analysis of the Results

Timeline types

Nine of the participants of the focus groups believed in a model of time with a parallel timeline. Three of them thought that if a time traveller arrived in either the past or the future, a new timeline would begin from that point forward, and the original timeline would remain untouched and in parallel to the new one, as shown in the guyline in Figure 56.

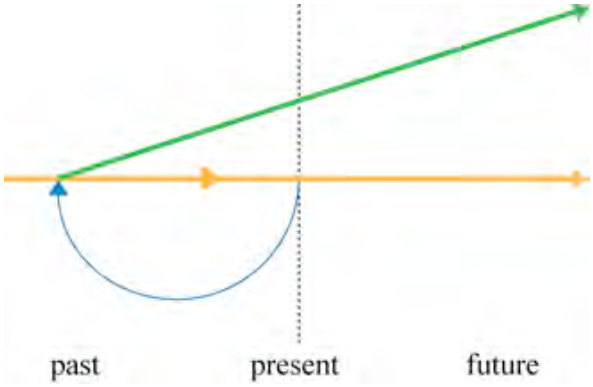


Figure 56: A guyline diagram of a parallel timeline with an open past and an open future

Another three participants thought that the past could not be changed, so that no new timelines could be created in the past. Therefore, if a time traveller arrived in the past, they would not be able to change any events, objects or people. There are two ways this could happen:

- The time travellers would only be able to observe themselves in the past and would not be seen, like a ghost or an angel.
- They would be able to go back in time and enter their bodies so as to re-experience the same past events, but with different thoughts and feelings.

In either case all past events remain untouched; however, once they returned to the point in time when their journey began, a new diverging timeline would be created from that point forward into the future in parallel with the untouched original timeline, as they would now have their new-found knowledge. This is shown in the guyline diagram in Figure 57.

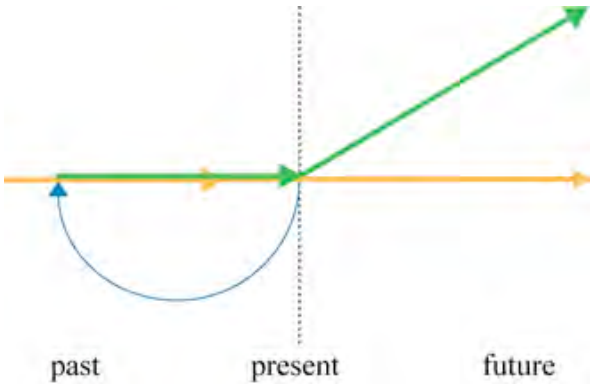


Figure 57: A guyline diagram of a parallel timeline with a closed past and an open future

The essential difference between the models of time shown in Figure 56 and Figure 57 is that the first will allow for a new parallel timeline to start diverging at any point along the timeline, whereas the second model will not allow a new parallel timeline to start to diverge in the past because the past must remain fixed.

The final three participants believed that a parallel timeline could be created using the closed-closed rule. In Chapter Five, I concluded that this was an impossible combination; however, when after careful consideration three physicists chose this combination, I was forced to reconsider my position in case a new model of time had emerged.

My original assumption about a closed-closed rule was that a new timeline could not be created in the past or the future because all of the events along this timeline were fixed in time. Therefore, I considered a closed-closed rule and a fixed timeline to be synonymous. However, a new parallel timeline could be created for a time traveller arriving in the past, but it would have to contain exactly the same events as the original timeline in exactly the same order, as shown in Figure 58.

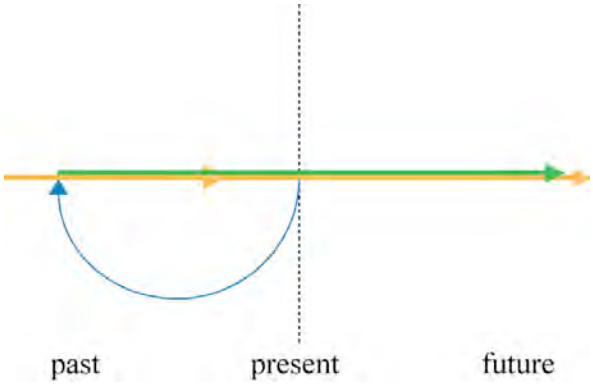


Figure 58: A guyline diagram of a parallel timeline with a closed past and a closed future

An example of this new model of time is *Slaughterhouse Five* (1972), which I had originally categorised as having a fixed replacement timeline. Whenever the protagonist went back or forwards in time, the same events took place in exactly the same way over and over again, but his observations, thoughts and feelings were different each time, and therefore, so was his experience because his perception had changed. It could be concluded that each time he went back or forward and re-experienced these same events, it was on a parallel timeline, and therefore that all of his time travel journeys existed in parallel to each other. The position of the timelines on all my guyline diagrams is always determined by the external events they represent. In this instance where a new experience of the same events occurs, the colour of the timeline changes to green to show that this new timeline is in parallel to the original, as shown in Figure 58 and also in the first half of Figure 57.

A fixed timeline, on the other hand, is more applicable to a film like *Twelve Monkeys* (1995) in which the protagonist makes several return trips to the past, where he interacts with the past making what he thinks are changes. However, all they do is create his known history, so that when he returns to his present, nothing has changed. Figure 59 shows that there is clearly only one timeline in a causal loop scenario like this one. He is not going back and re-experiencing or reviewing the past, nor is he going back and creating exactly the same timeline again. He is creating it for the first and only time in his personal experience, even though the event has already taken place from an external observer's point of view.

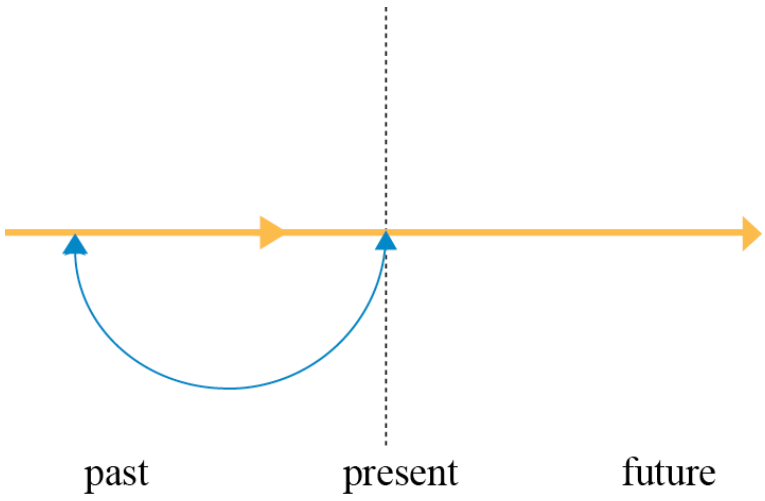


Figure 59: A guyline diagram showing a return trip back and forth on a fixed timeline with a closed past and a closed future

Therefore, a new model of time emerged from the analysis of the interview data that I had previously considered to be impossible: a parallel timeline with a closed past and closed future. After checking all eleven films that had a closed past and closed future, it was found they were all correctly categorised as having a fixed timeline except for *Slaughterhouse Five* (1972).

Timeline Properties

I had already established that a parallel timeline or a replacement timeline could have three different properties. It could:

- Diverge from where the original timeline used to be.
- Diverge and then converge.
- Behave in a manner similar to a double well.

However, after the latest model of time emerged, it was shown that both a parallel timeline and a replacement timeline could also have a fourth property, which was to follow the fixed path where the original timeline used to be.

Therefore, it appears that there are really only two types of timeline:

1. Parallel timeline
2. Replacement timeline

Therefore, I no longer defined 'fixed' as a type of timeline; it was now a property that could be applied to either of the above types of timeline.

When I reclassified the reviewed films to fit into one of the two types of timeline, the vast majority of them used a replacement timeline rather than a parallel timeline as shown in Figure 60.

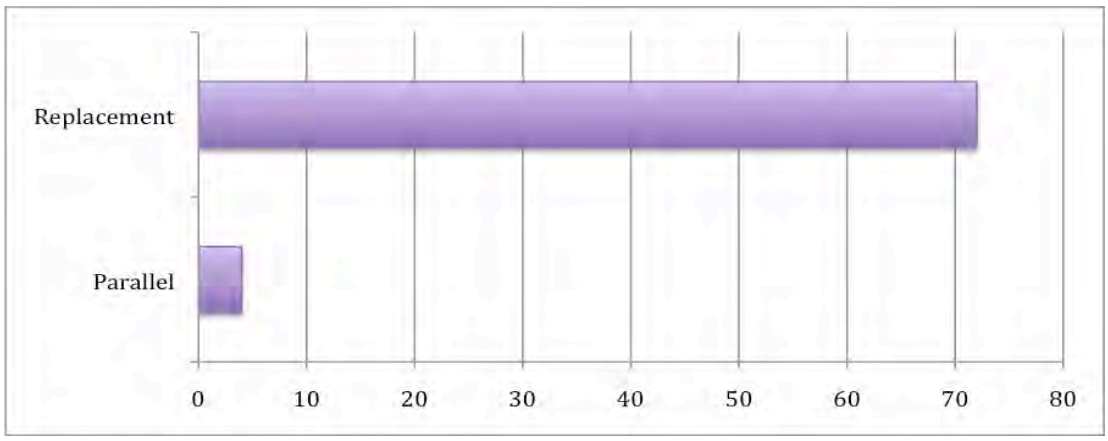


Figure 60: Percentage of films that used a parallel or replacement type of timeline

When the data from the interviews was also reclassified to correspond to one of the two timelines, both types of timeline were equally represented as shown in Figure 61.

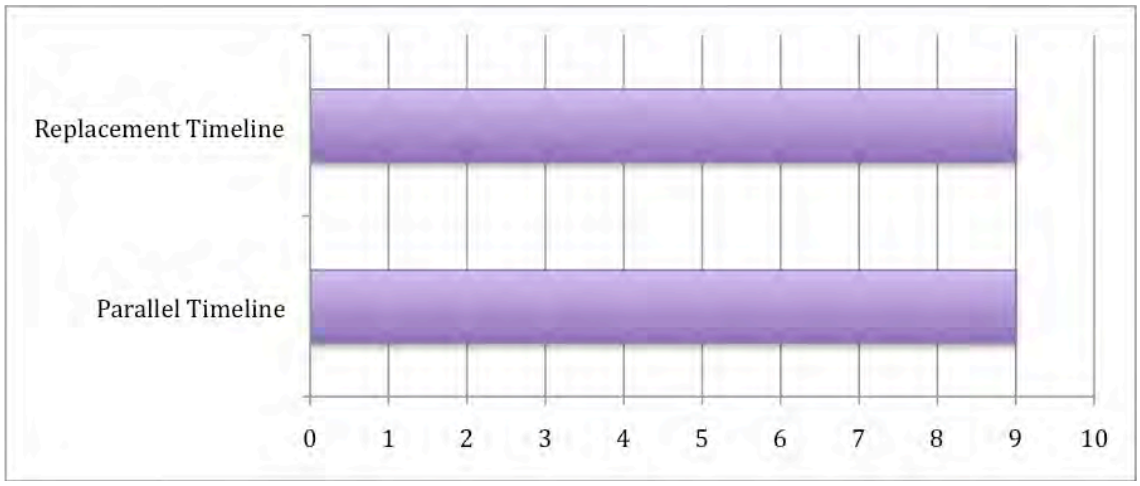


Figure 61: Number of participants who chose a parallel or replacement type of timeline

However, half of the participants in Figure 61 had a physics background, which meant that they would have some familiarity with the concepts of parallel timelines because of an established interpretation of the implications of quantum physics. Therefore, this data could be skewed towards their beliefs, so separating the result of the physicists from the others shows a clearer picture. When the data is broken down, it shows that the majority of physicists believed in parallel timelines, whereas the majority of participants without a physics background believed in replacement timelines. Figure 62 shows how much difference having a physics background made to which timeline the participants chose.

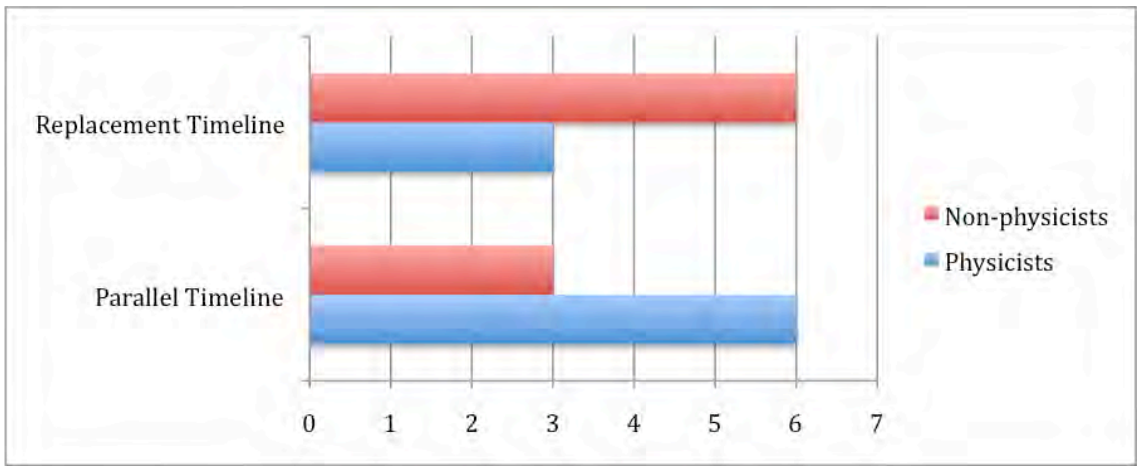


Figure 62: Number of physicists compared to non-physicists who chose the different types of timeline

These two types of timelines (replacement and parallel) could have any one of the following four properties: diverging, converging, double well, or fixed. Table 16 shows a matrix of these eight possible timelines with an example of a guyline graph for each.

Comparison with the theory

When comparing the theories of time reviewed in Chapter Three with the eight possible timelines shown in Table 16, it became apparent that one of these theories did not match any of my timelines. It was the theory of time from Indian philosophy known as the perennial philosophy, which has an infinite number of parallel timelines all existing alongside one another, and with each one having a slightly different destiny.[1]

In the other parallel timelines discussed up to now, a time traveller always creates a new timeline on his arrival in the past. This exists in parallel to the timeline that they left. There is not much point in a time traveller going back in time to change anything because any changes they make will only apply to their new timeline – they will not affect the timeline from which they came. The other disadvantage is that a time traveller can never return to where they came from by travelling back to the future, as forwards time travel will only move them further along their new timeline. This is, of course, unless they master the art of jumping between parallel timelines. In this case, they could travel forward in time and then jump across to the parallel world from which they came.

[1] The infinite unchanging reality of the perennial philosophy is discussed in the section, 'Free will and determinism' on page 47 in Chapter Three.

There were no movies that I reviewed where time travel was combined with jumping from one parallel timeline to another.

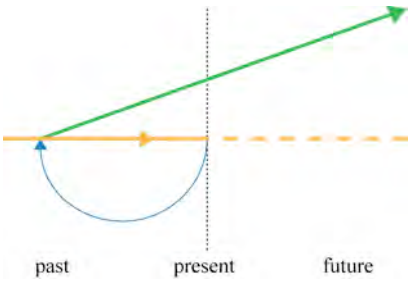
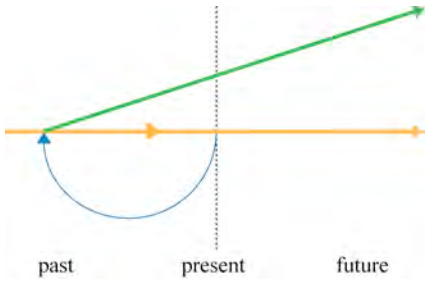
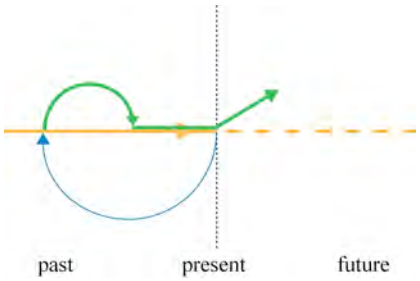
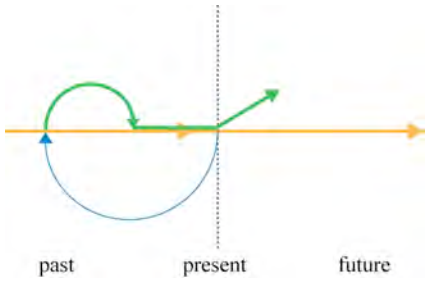
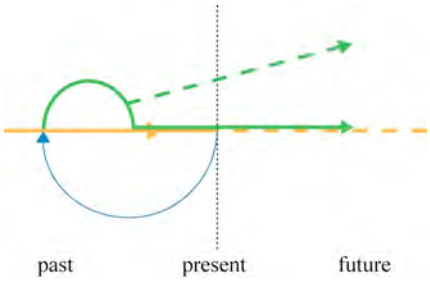
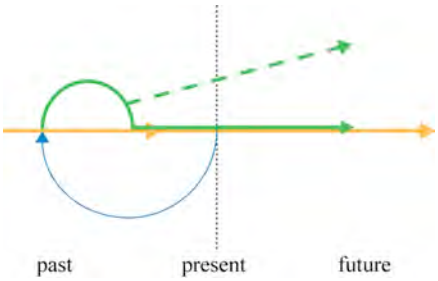
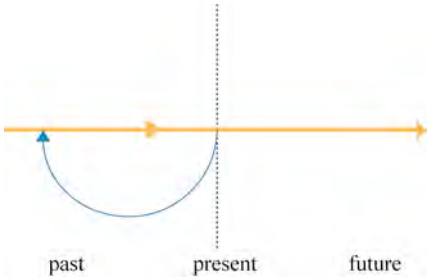
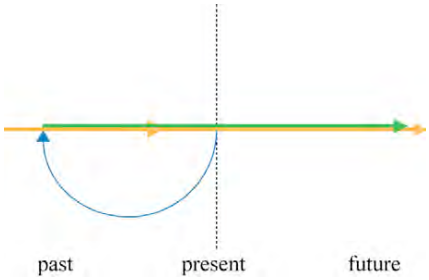
Timeline Property	Replacement Timeline	Parallel Timeline
Diverging		
Converging		
Double Well		
Fixed		

Table 16: A matrix of the eight different timelines as a result of having two types of timeline each with four possible properties

In a model of time with an infinite number of timelines, when a time traveller arrives in the past, no new timeline is instantly created; it is already there because every possible parallel timeline already exists. And if you were to step out of time altogether, you would see an infinite number of timelines branching out from a single point that began at the singularity of the big bang and also from every point along the way.

Therefore, a new timeline property has emerged, and I shall refer to it from now on as the 'multiple' timeline. The strict interpretation of the multiple timeline is as above with an infinite number of timelines branching out from every point along the timeline. The other interpretation is where a large number of timelines are branching out from a large number of significant points along the timeline. So the definition that I am going to use for a multiple timeline is one that could have a large finite number, or an infinite number of timelines branching out from an infinite or large finite number of points along the timeline. The main feature that distinguishes it from the other timeline properties is that at any point in time there is an infinite (or large finite) number of versions of an event that exist on different timelines, all in parallel to each other. It could look like the guyline drawn in Figure 63; or with an infinite number of different green timelines, which of course is impossible to draw.

The protagonist of *The One* (2001) travels between different parallel timelines killing 122 other versions of himself, and the characters in the film *Cube 2: Hypercube* (2002) do interact with different parallel timelines. In neither of these films is it specified that there are an infinite number of parallel timelines, but there are certainly multiple ones.

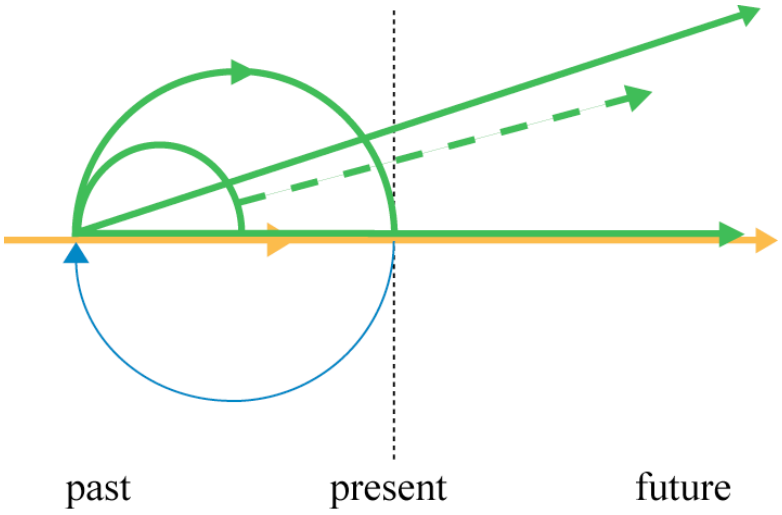


Figure 63: A timeline with a 'multiple' property has many different timelines or even an infinite number of them in parallel to the original timeline

A multiple timeline is closed because the events on any timeline can never be changed. When a time traveller makes a journey to the past, they do not create a new timeline because they would find themselves on a parallel timeline that already exists. Therefore, any events that they think they are changing are events on a parallel timeline that were supposed to change in that way.

This now leaves us with five timeline properties to choose from (diverging, converging, double well, fixed, or multiple) and also two types of timeline (replacement and parallel). Note that the property 'multiple' can only be applied to the parallel type of timeline because the nature of the replacement type is such that only one timeline can ever exist at any moment in time. So this will create nine different possible timelines from which to choose.

Analysis of the Full Data Set of Films

There were 32 films in Appendix II that met my criteria for time travel. They were not included in Chapter Four because I reviewed them after the deadline of this initial study. So, I have now added them to the original data set of 100 films, and all 132 films are shown Table 21 in Appendix V, which indicates the timeline property, the type of timeline and the past-future rule used in each film. Where appropriate, some of these attributes were labelled as 'undefined'. I was then able to analyse this data in regard to the past-future rules and the timelines that were used or not used in these films.

Past-future rules

There were 24 films from the original data of 100 films that had an undefined past-future rule, and hence could not be included in this section about rules. 11 of the 32 additional films also had an undefined past-future rule. After removing these 35 films, this left 97 films that made up the new data set, which was then used to show how often the four past-future rules were used in them.

Table 3 shows how many films had used each past-future rule. The first number in each cell of the table represents how many films from my original data set used that rule. The second number represents how many films from the additional data used that rule. The third number in each cell is the sum of the first two numbers, which gives the total films

reviewed in this thesis that used each of the rules. A tick or a cross is used to indicate whether or not the rule was chosen by at least one member of the focus groups.[1]

Past-future rule	Films	Interviews
Open-open	59 + 13 = 72	√
Open-closed	2 + 2 = 4	×
Closed-open	4 + 1 = 5	√
Closed-closed	11 + 5 = 16	√

Table 17: The number of films reviewed that used each of the past-future rules

It can be noted that the open-closed rule is the only one that was not chosen by at least one member of the focus groups even though this rule is self-consistent, and was used by four of the films. The open-closed rule allows for changes to events in the past so long as the new timeline re-joins the original timeline at some point before the time traveller begins their journey. Four films that used this model of time:

- *Groundhog Day* (1993) and *The Last Day of Summer* (2007) have very similar plots, where the protagonist is trapped in a time loop forever changing the past until he creates the only future that can ever take place.
- *Terminator 3: Rise of the Machines* (2003) allows past events to be delayed, but they can never be stopped, as they need to take place for the terminators to come back, so that the timeline will remain self-consistent.
- *The Seeker: The Dark Is Rising* (2007) involves Will taking several trips to the past, where he alters history each time, but nothing has ever changed when he returns to his present.

[1] The sample size of the interviews was too small and skewed towards participants with a physics background for the numbers gained from the verbal survey to be used for statistical comparisons.

The other rules existed in the personal model of time of at least one of the participants in the focus group interviews, and each of them was used in at least one of the films in my data set.

Timelines

There were eight films from the original set of 100 that involved only forwards time travel; therefore, only 92 contained enough information for the property of the timeline to be determined. Nine of the additional 32 films also had an undetermined timeline, which left only 23 of them. So, after removing 17 of the 132 films, the new data set was then used to show how often the nine timelines and four past-future rules were used in these 115 films. Table 18 shows which of the nine timelines were used in each of these 115 films. The first number in each cell of the table represents how many films from my original data set used that timeline. The second number represents how many films from the additional data used that timeline. The third number in each cell is the sum of the first two numbers, which gives the total number of films reviewed in this thesis that used each of the timelines. A tick or a cross is used to indicate whether or not the timeline was chosen by at least one member of the focus groups. There is a question mark next to the multiple timeline because this timeline was not offered to the participants, so they were unable to accept or reject it.

Timeline Property	Replacement Timeline	Parallel Timeline
Diverging	33 + 12 = 45 √	5 + 0 = 5 √
Converging	21 + 5 = 26 √	0 + 0 = 0 ×
Double Well	21 + 1 = 23 √	0 + 0 = 0 ×
Fixed	10 + 4 = 14 √	1 + 0 = 1 √
Multiple	Not possible	1 + 1 = 2 ?

Table 18: The number of films reviewed that used each of the nine timelines

It can be seen that all but two of the possible timelines were represented in at least one film: the converging parallel timeline and the double well parallel timeline. At the start of *Sliding Doors* (1998) the timelines diverged, but in the middle of the film it appeared that the new timeline might have been converging back towards the original. However, with closer analysis, it was just that several external events were taking place in both timelines at the same time. The timeline completely diverged at the end of the film when Helen died in one timeline, but not in the other. Although the film was categorised as a diverging parallel timeline, it came close to being categorised as having a double well parallel timeline. If Helen had not died at the end of the film, she could have ended up being with James in both timelines, and then the film would have been classified as using a converging parallel timeline. Therefore, there is no reason why a successful film could not have a script that uses a converging parallel timeline.

The multiple parallel timeline was not presented at the interviews, so it was neither accepted nor rejected by the participants, and therefore we cannot say for sure whether it would have been chosen or not.

Interestingly the two timelines not used by the filmmakers were the same two timelines not chosen by any member of the movie-going public. There could be a variety of reasons for this. Following are three of the possible reasons that relate to the relationship between personal models of time and those used in film:

- None of the public had a personal model of time that included either of these two timelines because they had never seen a film that used them.
- No films have been made using these two timelines because the filmmakers think that none of the public would believe them valid.
- The data are misleading and/or coincidental.

I have no evidence to suggest that the first argument is correct. In the interviews that I carried out with the movie-going public, they were happy to use the films they had seen as examples of the different models of time, but there was nothing to suggest that any of the participants was basing their personal model of time on the films. However, research with an aim to discover if there was any truth in this argument could be conducted in the future.

There is no evidence to suggest that the second argument is true. It may well be true, but in order to support this argument, further research would have to be carried out including interviews with the filmmakers.

The third argument is not so black and white. The final data set was made up of 132 films, which included all the popular films involving time travel and other temporal phenomena, plus a good number of foreign films and several rare films. It is unlikely that any of the unreviewed films would be using different models of time, and even if they were, they would not materially affect my data. I believe that these 132 films are a representative sample of all time travel films released or available in Australia, and therefore, I do not believe that the film data could be misleading.

The number of people involved in the interviews was small. The intention of that study however was not to create a statistical survey of what the movie-going public thought; it was to find out which of my models of time most closely represented their personal models of time. If a large-scale survey of the movie-going public were carried out, then it might be found that some people believed that one or both of the two unpopular models of time were valid for them.

Constructing the models of time

A complete comprehensive set of models of time can be constructed by creating a matrix of the two types of timeline, the five timeline properties, and the four past-future rules. One cell on the matrix produces a model of time that is not possible because the replacement type of timeline cannot have a multiple property. Also, not all four past-future rules are applicable to every timeline property; a diverging timeline cannot be closed-closed for example. The outcome is that this matrix yields 21 possible models of time as shown in Table 19.

Earlier in this chapter, it was noted that only 97 of the 132 films reviewed had fully defined past-future rules. Each of these 97 films was examined to determine which of the 21 models of time it was using, and the results are shown in Appendix V.

I placed these results into the cells of the matrix in Table 19. The first number in each cell represents how many films from my original data set used that model of time, and the second number represents how many films from the additional data used it.

`Timeline property	Past-future rule	Replacement timeline	Parallel timeline
Diverging	open-open	23 + 9 = 32	2 + 0 = 2
	open-closed	2 + 0 = 2	0 + 0 = 0
	closed-open	3 + 1 = 4	0 + 0 = 0
Converging	open-open	17 + 3 = 20	0 + 0 = 0
	open-closed	0 + 2 = 2	0 + 0 = 0
	closed-open	0 + 0 = 0	0 + 0 = 0
Double Well	open-open	17 + 1 = 18	0 + 0 = 0
	open-closed	0 + 0 = 0	0 + 0 = 0
	closed-open	1 + 0 = 1	0 + 0 = 0
Fixed	closed-closed	10 + 4 = 14	1 + 0 = 1
Multiple	closed-closed	not possible	0 + 1 = 1

Table 19: A matrix of the 21 models of time that make up the complete comprehensive set of models of time.

Applying the models of time

Now that my models of time are a complete set, they can be used to find other gaps in my film and interview data. Earlier in this chapter, I discussed the types of films that use a closed-closed rule, and looked at why there are no films that use a parallel timeline when it is converging or a double well. So, next I wanted to analyse the results after collapsing Table 19 into a format without the timeline properties, which is shown in Table 20. I then added a tick or a cross to indicate whether or not each model of time was chosen by at least one member of the focus groups.

Past-future rule	Replacement timeline	Parallel timeline
open-open	57 + 13 = 70 √	2 + 0 = 2 √
open-closed	2 + 2 = 4 ×	0 + 0 = 0 ×
closed-open	4 + 1 = 5 √	0 + 0 = 0 √
closed-closed	10 + 4 = 14 √	1 + 1 = 2 √

Table 20: A simplified matrix of 8 models of time defined by the two types of timeline and the four past-future rules

Table 20 shows that there are two models of time that have not been used by any of the films that I reviewed.

In the first one, none of the participants of the interviews believed that the model of time that has a parallel timeline with an open past and a closed future represented their personal model of time, and it was not found in any of the films in my data set. If this model was used in a film, there would only be one future as in *Groundhog Day* (1993), but each adventure in the past would exist in parallel, rather than replacing the previous one. The story would work equally well, as nothing would change from the protagonist Phil Connor's perspective. However, the story would gain nothing from the past adventures remaining in parallel, so there would not be much point in doing it.

Alternatively, the storyline would change dramatically in *Terminator 3: Rise of the Machines* (2003) if a model of time that has a parallel timeline with an open past and a closed future were used. When the Terminator arrived from the future a parallel timeline would be created, which would start to diverge away from the original timeline. However, when the Terminatrix arrived a few minutes later, she would not find the first Terminator, as he would be on different parallel timeline to the one she creates upon her arrival as shown in Figure 64, so the story would not work at all. It is therefore clear why this model of time has never been used.

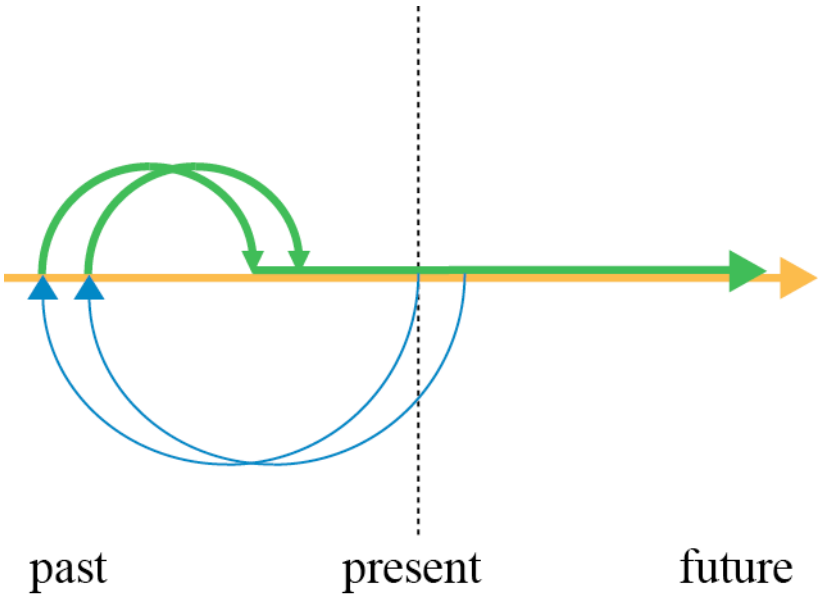


Figure 64: A guyline showing two time travellers leaving a converging parallel timeline at slightly different times

The second model of time that was not used in any film that I reviewed has a parallel timeline with a closed past and open future, and a guyline of this type of films is shown in Figure 65. Although this model was not found in any of the films in my data set, it is interesting to note that some of the participants in the interviews believed that it most closely represented their personal model of time.

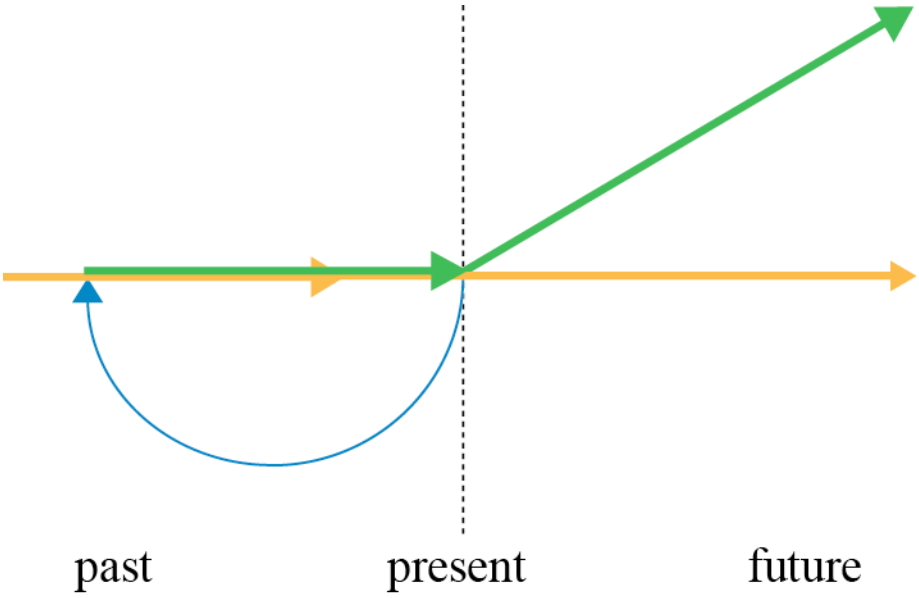


Figure 65: A parallel timeline with a closed past and open future

This model would produce a film with an open future like *Click* (2006) or *A Christmas Carol* (2004) in which the protagonist is unable to change the past, but does gain information whilst there. He uses this information to change the timeline when he returns, except that with this model of time it would exist in parallel to the original timeline. The story would still work in the same manner, and this is how some people believe that time works in reality: a past that cannot be retrospectively changed with multiple futures that exist in parallel.

There were some films in my data set that could have been identified as using this model of time, such as *It's a Wonderful Life* (1946), *The Family Man* (2000), or *Me, Myself, I* (1999) all of which contrasted events on two parallel timelines. The protagonists in these films were able to make changes to their future, but as they did not attempt to change their past, it cannot be said whether the past is open or not. Therefore the past remains undefined, so a complete model of time could not be constructed for them. For a film to have such a model of time, it would need to have an unchangeable past like *A Christmas Carol* (2004) and then as it moved forward into the future, we would have to be able to see the original timeline and the new timeline progressing in parallel. I expect we will see a film like this one day, and it could even be a remake of *A Christmas Carol.*

To summarise, so far there are four models of time that have not been used in any of my films that I have discussed:

- Open-closed parallel timeline (likely to be produced in the future)
- Closed-open parallel timeline (likely to be produced in the future)
- Converging parallel timeline (very unlikely to be produced in the future)
- Double well parallel timeline (likely to be produced in the future)

Each of the above is an overlapping general category, which contains three specific models of time. In total, they represent eight of the models of time shown in Table 19. There were also a couple of specific models of time with replacement timelines that were not used in any of my films: the closed-open converging timeline and the open-closed double well timeline:

The first, if used in a film, would have a past like *A Christmas Carol* (2004) where the protagonist could go back and review the past, but not interact with it; however, they could interact with events in the future and make temporary changes, but the timeline

would always converge back to the original. This would allow the protagonist to learn from his mistakes in the past, and make changes to his life in the future, but he would not be able to change his destiny. It is possible that a film like this could be produced, but because this theme is rather dark, it would probably have limited appeal, and therefore would be more likely to be made as an art-house film rather than a Hollywood blockbuster.

The third, if used in film, would have a past that could be changed, but whatever was changed would cause the timeline to return to its original position just before the time traveller departed. This would be like the film *Déjà Vu* (2006) - except that Doug would not have been able to stop the ferry explosion, and from that point on he would not be able to alter his future or change his destiny. It would be a little like *Back to the Future* (1985) except that when Marty returns to the present, he would find that he is unable to alter his future or change his destiny. I cannot see a reason why you would want to do this in a plot, but that does not mean that a filmmaker would not one day do it.

- Closed-open converging replacement timeline (unlikely to be produced)
- Open-closed double well replacement timeline (a vague possibility)

In summary, I found six potential types of time travel film (which represent ten of my models of time) that have not yet been produced. Based on the above discussions three are likely to appear someday soon, one is a vague possibility, another is unlikely to be produced, and the last is very unlikely.

Determining a person's model of time

For future work in the area of determining a person's personal model of time, I have developed a scheme based on the above analysis. In order to elicit a model of time from someone, there would be no need to ask the person to choose from a list which model of time they believed best represented their personal model of time. It could be determined by combining the timeline that mostly closely fits their personal model of time with the past-future rule that they would apply to it. This would be implied as soon as they answered the following three multiple-choice questions:

1. Do you believe in parallel universes or not? (Do you think that at the time traveller arrives they are experiencing events that are replacing the original ones, or events that exist in parallel to the original ones?)

2. Which of the following properties do you think the new timeline will have?

    a) The events will continue to diverge away from the original events.

    b) The events will start to diverge away from the original events, but then converge back towards them?

    c) The events will start to diverge away from the original events, but whether they then converge back or not depends on how significant the changes are that the time traveller is making.

    d) The events will always follow those of the original timeline.

    e) All of the above will exist at once in parallel to each other.

If the person answers question two with d) or e), then they clearly believe that time is closed-closed, so there is nothing more to ask them. If they answered question two with a), b) or c) then they will need to answer question three:

3. In which of the following do you believe that the events are changeable?

    a) The future only

    b) The past only

    c) The past and the future

For example, if someone answered Question 1 by stating that they did not believe in parallel universes, and then chose answer a) from Question 2, and answer a) from Question 3, we could say that their personal model of time travel was an ‘open-closed diverging replacement timeline’ as shown in Figure 66.

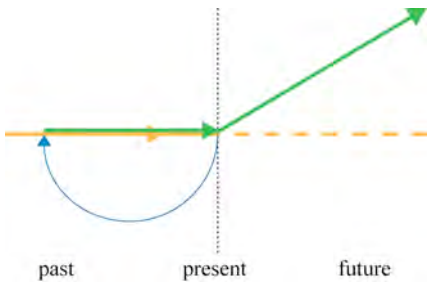


Figure 66: An closed-open diverging replacement timeline

Summary

In this chapter, when comparing the film results from Chapter Four and the interview results from Chapter Five, I found that the filmmakers had a strong preference for using the rule with an open past and open future, and also a strong preference for the replacement timeline. The participants of the interviews, however, were split more evenly between the first three past-future rules, with the most popular being the closed past, open future rule, and they showed little difference in preference between the replacement and parallel timelines.

In the analysis of results, a new timeline emerged: the fixed parallel timeline. I developed a more accurate structure for the timelines by establishing that there were only two types of timeline, with each having one of four possible timeline properties.

When comparing the past-future rules and timelines with the theories of time from Chapter Three, I uncovered the multiple timeline property, which could only apply to the parallel timeline. This left me with nine possible timelines and four past-future rules. I then analysed these fully developed past-future rules and timelines against the full data set of films, where I discovered which of them are not used in any of the films and which did not match anyone's personal model of time. However, the reason for this was not clear, and I suggested that further research could be undertaken to determine the reason and judge how valid this finding was.

I finished by combining the nine timelines with the four past-future rules to create a comprehensive set of 21 different models of time, and described a method for eliciting someone's personal model of time by asking three simple multiple-choice questions.

In conclusion, a comprehensive set of models of time was constructed using my research data. It is useful because other researchers can apply it to analyse their own data, and it is also useful for outlining a process for determining a person's personal model of time.

In Chapter Seven, I will answer the main research question of this thesis. I will also make conclusions about the findings of this thesis, discuss its significance, the contributions it makes, state its limitations, and finally make recommendations for further study.

CHAPTER SEVEN: CONCLUSION

> *I am sure we will figure out how to time travel. Then we will be able to go back in time and fix the things that are messed up. Unless, of course, people from the future have already time travelled back and fixed everything, which means that this is the best its ever gonna get.*
>
> - Craig Ferguson, comedian[1]

In this chapter, I summarise the findings of the previous chapters, in the process answering my three research sub-questions. I answer my main research question while making conclusions about the different models of time travel found in this thesis including the past-future rules, the types of timelines and their properties. I highlight the significance and contributions that this thesis makes to researchers, educators, filmmakers, and authors. The limitations of this thesis are discussed, and finally I make recommendations for further study in the areas of science communication, cultural studies, and film studies.

Thesis Summary

In my literature review, I showed that many authors had emphasised that public perceptions about science can be influenced by film, and that the blurring of fact and fiction in film can be a problem if it leads to misconceptions about science. I also showed that many authors had suggested that science in film should be represented as accurately as possible, and that most contemporary filmmakers agree, as they now often choose to work with science consultants when making science-fiction films.

I also showed that various attempts have been made to draw timeline diagrams that accurately describe what happens when a character time travels in such films. I found that these diagrams were often difficult to interpret and contained limited information. What I discovered was missing was a consistent and comprehensive way for representing time travel trips in film and also a comprehensive set of models for comparing the model of time travel being used in various films, and that could also be used for determining the public's views about time travel and its consequences.

[1] Calvin (2009).

My main research question resulted from the findings of this literature search:

'Can the implicit models of time travel used in films be used to construct a comprehensive set of models about time travel and its consequences?'

I also formed the following three sub-questions:

1. What theories and ideas have researchers from science and philosophy produced about time travel?
2. What models of time travel can be constructed from films?
3. How do these models of time travel compare with the personal models used by members of the movie-going public?

In order to address sub-question one, in Chapter Three, I identified the theories and ideas that researchers from science and philosophy have produced about the nature of time, time travel and other temporal phenomena. I looked at the A-theory versus the B-theory of time, presentism versus eternalism, free will versus determinism, as well as some cultural perspectives on time, the arrow of time, and a universe without time. Forwards time travel was discussed including time dilation, relativity, suspended animation and cryogenic freezing. Various speculative theories about backwards time travel were reviewed such as faster than light travel, wormholes as time machines, warp drives, and time travel in superstring theory. I highlighted the possible solutions that researchers have suggested to overcome temporal paradoxes, such as the self-consistency conjecture, the existence of parallel worlds, and Hawking's Chronology protection agency. Some psychologists' perspectives on mental time travel were also reviewed as well as discussing the possible reasons for people wanting to time travel. Finally, the physics of chaos theory was investigated and I looked at how the Butterfly Effect had been applied to both psychology and time travel.

In order to address sub-question two, the film study in Chapter Four enabled the determination of the model of time travel used in each of the 100 films that were reviewed. However, I was not able to determine the complete model for 24 of these films because as they used only future time travel, this prevented my knowing what was happening to the section of the timeline that was by-passed. When the remaining 76 films were analysed, four different rules were identified: the open past, open future rule (78%), the closed past, closed future rule (14%), the closed past, open future rule (5%),

and the open past, closed future rule (3%). I also identified three types of replacement timelines: the diverging timeline (36%), the converging timeline (24%), and the double well timeline (24%), as well as the fixed timeline (14%) and the parallel timeline (3%). 13 distinct models of time travel were possible when these four past-future rules were combined with the five types of timeline; however, the films in my data set had used only nine of these models, which meant that four of them were not used in any of the films. To help with my analysis of the films, I devised 'guyline' graphs to show in diagrammatic form how time was behaving, so that I could determine which model of time travel was being used.

In order to address sub-question three, in Chapter Five, I used a verbal survey in three focus groups with members of the movie-going public and also an interview with a filmmaker to elicit the personal models of time travel of each participant. I discovered that each of the five timelines and each of the four past-future rules was chosen at least once by the participants – except for the rule with an open past and closed future. I also discovered that the participants were equally divided on whether the replacement or parallel type of timeline would be created as a result of backwards time travel, and that only one participant chose the fixed timeline. When separating the results of the participants with no physics background, I noticed that the majority of them chose the replacement timeline, whereas the majority of physicists favoured the parallel timeline. I also found that all of the non-physicists believed in a past-future rule with an open future, which is compatible with how the human mind experiences time; whereas about half of the physicists believed in a closed-closed rule, which is compatible with the block universe – the most common interpretation of the theory of relativity. Combining the types of timeline with the past future rules produced eight possible models of time, and I found that six out of the eight possible models of time were valid for at least one member of the moving going public. The two missing models were the ones that included the rule with an open past and closed future.

In Chapter Six, I compared and synthesised the models of time travel that I had identified from the previous chapters with the personal models used by members of the movie-going public. I discovered that the filmmakers had a strong preference for using the open past, open future rule, whereas the members of the movie-going public who participated in the focus groups had a strong preference for the open future, closed past rule. The filmmakers had a strong preference for the replacement timeline, whereas the

participants of the interviews showed little difference in preference between the replacement and parallel timelines. The fixed timeline was relatively unpopular in both studies.

While I was analysing these results, I discovered that all of the timelines identified in the previous chapter either belonged to the parallel or the replacement type of timeline, and that either of these two timelines could have one of the following four properties: diverging, converging, double well, or fixed. After further development of the theory, I concluded that the parallel timeline could have a fifth property named 'multiple' that allowed for up to an infinite number of timelines to exist in parallel to the original timeline. However, this new property could only be applied to the parallel type of timeline because my definition of the replacement type of timeline is that only one timeline can ever exist at any moment in time.

I concluded the analysis by combining the nine timelines with the four past-future rules to create a comprehensive set of 21 distinct models of time.[1] Ten of these models of time travel were not used by filmmakers in any of the films I reviewed. The possible reasons for this were discussed, and I determined for each of these unused models how likely it was that a time travel film using them would be produced in the future. I also looked at why some of the 21 models of time were not a match for the personal model of time of any of the focus group participants; however, the reason for this was not clear. Further research with a larger sample could be undertaken to determine the reason and judge the validity of this finding.

Thus, from my investigation of the three sub-questions of this thesis, I developed a novel and comprehensive set of models of time travel and a method for eliciting a person's personal model of time travel by asking three simple multiple-choice questions.

Conclusion

My main research question was: Can the implicit models of time travel used in films be used to construct a comprehensive set of models about time travel and its consequences?

[1] Not every past-future rule could be applied to every timeline property. For example, the fixed timeline is closed in both the past and future, so could never be open at any point in time.

The 21 different models of time travel that I have developed clearly demonstrate that by using time travel films it is indeed possible to construct a comprehensive set of models about time travel and its consequences.

The guyline graphs that I devised proved to be a very useful way of showing in diagrammatic form how time was behaving when analysing a film, and hence determining which model of time travel was being used. My guylines differ from most other timelines in that they have a y-axis as well as an x-axis. The y-axis shows how far the events have deviated from the original events, which is useful extra information especially when considering timelines that diverge back towards the original. The origin (where the two axes meet) indicates the moment when the first time travel began. All time beyond this point is the time traveller's future, and all time before this point is their past. Again, this is useful information, because it allows the reader to see whether the rules about the openness of time in the past differ from those in the future or not. These guylines could have many other applications, and have the potential to be used by other researchers or filmmakers to visually explain what is happening with the various timelines in a story.

The set of models of time that I developed in this thesis was also useful because the models helped me to have structured conversations with the participants of my focus groups. The key questions in my focus groups were grounded in the models of time travel that I had determined from reviewing the films. The models were also of great help to me when analysing the discussions that took place in the focus groups and therefore could provide a focus for future discussion with members of the public, thus enabling more exploration of public views. The three multiple-choice questions that I devised on how to determine someone's personal model of time were derived directly from the comprehensive set of models of time travel that I developed in Chapter Six.

Further Contributions of This Study

A contribution that this thesis will make in the future is that lecturers and teachers will have an increased awareness that there are multiple different models of time travel in which the public believe, so that when they are teaching the philosophy or physics of time they will have a better understanding of how to approach the teaching of the subject to their students.

As shown in this thesis, a transgression of one of the laws of physics in a time travel film can cause viewers to suspend their disbelief for the duration of the film, or can lead to a science misconception. It will be important to know whether viewers are able to understand this transgression or whether it leads to further misconceptions.

Knowing which the models most closely fit the movie-going public's beliefs about time travel will also help filmmakers, novelists and playwrights when their writing involves time travel. My research clarifies the various possible models of time travel so that they can be applied in a consistent way. It will make clear to the writer which model they are dealing with, and then they will know the pitfalls, consequences and opportunities inherent in using a particular model.

There are many games that involve time travel: computer, video, pen and paper, board, and role-playing games. For example, there are 99 software games listed that use time travel as a storyline element and 17 more that use time travel as a gameplay element ("List of games containing time travel," 2012). The results of this research will be useful in the development of these games, or in the design of any new games involving time travel for all of the above reasons.

Time travel is an area of theoretical science waiting for technology to advance sufficiently before it can move into the realms of experimental science. All emerging technologies need to be identified well before they become available to the public, so that informed discussions can take place between politicians, industry, scientists and the general public. If not, then public opinion may well become swayed against these technologies before the science has even been considered.

Limitations of the Study

This study focuses on the models of time travel employed in films. A possible limitation is the extent to which the models can be applied more generally to discussions about the nature of time itself. Certainly some of the issues I have raised are useful, such as the attractions of parallel timelines and whether the past or future is open or closed. Other issues, however, such as time reversal, our perception of time with age, or the suspension of time, such as through trauma, are not covered by my models. In my study, I excluded any film using immortals, or people who aged at a different rate to those around them because I considered this to be a biological phenomenon rather than a temporal one, and therefore the film was not considered by me to involve time travel.

My cut-off point for my initial film study was when I had finished reviewing 100 films that met my criteria, which was at the end of 2008. I was satisfied that I had reached a saturation point because I was not encountering any new models of time travel. I did continue to watch time travel films for another year without finding any new models of time travel. During the synthesis stage of my research, 17 of the 134 films reviewed were ruled out because they involved only forwards time travel, and therefore did not contain enough information for the property of the timeline to be determined. I would consider that the findings from the remaining 117 films were transferable because my sample size was more than 25 % of all time travel films that I found that met my criteria.

The set of models of time travel that I developed was comprehensive for the 117 films that I reviewed, but I am not suggesting that these models could not be refined or enlarged in the future.

The focus group study came to an end after three focus groups and a single one-on-one interview, which meant that a total of 25 members of the movie-going public had been interviewed. The high percentage of focus group participants with a background in physics limited the generalizability of focus group study.

Recommendations For Further Study

The following recommendations are made for future studies in science communication, cultural studies, and film studies.

Science Communication

In order to better understand what opinions and beliefs the general public have about time travel, the following studies could be undertaken.

- A large-scale survey so that statistical data can be gained about the personal models of time travel of the movie-going public, rather than just the qualitative data obtained from the limited number of focus groups that I held.
- The survey could also be extended to cover other members of the public who were not moviegoers, to find out whether or not their personal models of time travel differed significantly from members of the movie-going public.

- It would also be useful to differentiate the members of the public who had read novels involving time travel, and also those who had watched television shows involving time travel.

- Although my study differentiated between those who had and had not studied physics at an academic level, it would be interesting to go a step further and also filter the participants of the survey by those who had read popular science books on time travel for comparison with those who had not.

- Rather than just finding out which models of time travel the members of the public have adopted, a study could be carried out to find out what had attracted them to a particular model. What made that model attractive to them, and what made the others unattractive? Such a study would uncover underlying beliefs or misconceptions about time and time travel.

- A large-scale survey so that statistical data can be gained to identify all of the science misconceptions the public have about time travel and other temporal phenomena.

Cultural Studies

- A study of the public's beliefs about time travel with people from different cultures and/or religions.

- A study to expand the models of time travel to incorporate circular time and other non-western models.

Film Studies

In order to better understand the filmmaking process for time travel films, the following studies could be undertaken.

- Interviews with filmmakers to ascertain their personal models of time travel to find out if these are reflected in the films they make.

- Filmmakers could also be asked whether the model of time travel they chose to use in their film is influenced by what personal models they think their target audience has. For example, the vast majority of time travel films have an open future. Is this because the filmmakers think that their audience will like a film

better if it implies that they have some control over their future? Or is it because it is easier to generate a happy ending with films using this model of time? Hollywood has convinced itself that audiences insist on happy endings even though there is evidence to the contrary (Ansen, 2008).

- Research could be carried out to find out if there is a correlation between the success of a film and its model of time travel, taking into account any other factors that significantly contribute to the success of a film. This research could also include the following studies: to discover which models of time travel the audience most enjoy when watching a film, to discover the degree to which the audience are prepared to suspend their own model of time travel when watching a film, and also to discover how important it is that time travel films are self-consistent within their adopted model.

Final thought

Although backwards time travel is still only a possibility, it is better that we are prepared for its arrival as it may one day come. It is only then that we will find out which one of my models of time travel, if any, will accurately describe its reality.

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