The Paradoxes of Time Travel

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Humans have long been fascinated by the idea of visiting the past and of seeing what the future will bring. Time travel has been one of the most popular themes of science fiction. Most people have seen the TV series 'Dr Who' or 'Quantum Leap' or 'Star Trek'. You've probably seen one of the 'Back to the Future' or 'Terminator' movies, or 'Twelve Monkeys'. Time travel narratives provide fascinating plots, which exercise our imaginations in ever so many ways. But is the idea of travelling forward and backward in time pure fantasy—or can it be done? To be sure, not all time travel scenarios are coherent. But we hope to persuade you that the most common objections to the very idea of time travel have no real force.

What is time travel?

What would count as a genuine case of time travel, and what wouldn't? Time travel requires literally going to the past or future, not to some replica of it. Stumbling into Jurassic Park doesn't count. Similarly, merely seeing visions of the past or future or looking into a crystal ball (while remaining in the present) don't count. Scrooge is no time-traveller. Some discrepancy in time or the experience of it is required, but not all such cases of discrepancy count as genuine time travel: for example, crossing the international date line, coming out of a coma or suspended animation, taking LSD, having a hard night at the pub. In all these cases a person has been here all along; they just may not have been aware of it.

Time travel involves more than moving from one time to another. You were around an hour ago. You're around now. But that doesn't make you a time traveller in any interesting sense. What's needed is a discrepancy between the interval of time traversed from departure to arrival and the duration of your journey, such as traversing 65 million years in a very short time (as in the beginning of the Blast Back ride at Te Papa).

When one asks whether time travel is possible, there are several different things one might be asking. One might be asking whether it is physically possible. Is it compatible with the laws of nature in our universe or with the best physical theories of our day? Alternatively, one might be asking whether the very idea of time travel is logically or

conceptually possible. Can it be described without contradiction? If time travel is physically (and therefore logically) possible, one might ask whether we can produce a practicable scheme for actually doing it. 'Do we have the technology, Scottie?'

Relativity theory and closed timelike lines

It is widely known that the special theory of relativity, discovered by Einstein in 1905, has as a consequence that forward time travel is possible. One of the fundamental principles of special relativity is that the speed of light is constant. All observers, in whatever direction they are moving and at whatever speed, measure the same value for the speed of light. It follows from this principle that observers moving relative to one another measure different temporal intervals between the same events.

For instance, suppose that I am stationary and that you are travelling away from me at high speed with a light source. The source emits two flashes. Because the light seems to us both to be travelling at the same speed, yet has further to go to reach me, the interval between the flashes must seem longer to me than it seems to you. In particular, a clock carried in a fast rocket runs slow relative to a similar clock on Earth—and the faster the rocket travels, the slower the clock runs. This is known as the *time dilation effect*, and it implies that any traveller can, simply by travelling fast enough, become a time traveller. The pilot of a space rocket, coming back to Earth after her high speed journey, finds that while only a few years have elapsed for her, many years have elapsed on Earth. The faster she goes, the further in the Earth's future she arrives back.

This is no merely theoretical possibility. Even aboard existing aircraft, atomic clocks have measured small time dilations. In other words, these clocks—and the planes and pilots that carry them—travelled (ever so slightly far) into the Earth's future.

But what about backward time travel? Does current physics allow for the possibility of travelling into the past? In fact it does, although at this stage backward time travel, unlike forward time travel, is only a theoretical possibility. In Einstein's special and general theories of relativity, time and space are combined to form four-dimensional *spacetime*. Each point in spacetime is an *event*: a particular place at a particular time.

All the events that together comprise your life — from the event of your birth through to the event of your reading this page through to your future death — together form a four-dimensional 'worm' in spacetime. This worm is called your *worldline*. Each thing has its own worldline; and what we see when we look at an object at any particular instant is a three-dimensional cross-section of its four-dimensional worldline. **[illustration]**

This illustration shows one spatial dimension, plus time. You can see that if you stay still between times *x* and *y*, your worldline will be vertical between *x* and *y* (time passes, but you do not move in space). In general, the angle between your worldline and the time axis at a given time represents your speed at that time. **[illustration]** The worldline of a ray of light is standardly depicted as making an angle of 45 degrees with the time axis at

every point in time. If you turn on your flashlight for an instant at time *x*, the light will spread out in all directions at a 45 degree angle, forming a cone in spacetime known as a light-cone.

In relativity theory, nothing can travel faster than light. This means that people and objects cannot have arbitrary curves as their worldlines. Your worldline cannot bend over too far – that would be more than embarrassing. It cannot stray outside any light-cone emanating from any event in your past. A worldline that meets this requirement is called *timelike*. Thus, relativity theory says that the worldlines of objects must be timelike.

Doesn't this make backward time travel impossible? Wouldn't a time traveller's worldline have to bend back on itself, and look like this? **[illustration]** No, backward time travel is not ruled out. For in general relativity, spacetime itself may be distorted or bent. That's what massive bodies such as stars and black holes do: they distort spacetime.

It has been known since at least the 1940s that there are possible universes which obey the equations of general relativity, in which spacetime is so distorted that some timelike lines form closed loops. **[illustration]** They are timelike all the way around, and yet they end up in the past of where they started. These worldlines are called *closed timelike lines*.

If such a closed timelike line existed in our universe, it would be a route into the past. We would not need any special vehicle, such as Dr Who's *Tardis*, to travel along it. We would only need an ordinary, every-day rocket or space-ship. By flying off along a closed timelike line, we would end up in the past. Kurt Gödel, who in the 1940s drew attention to the possibility of closed timelike lines in relativity theory, wrote that 'by making a round trip on a rocket ship in a sufficiently wide curve, it is possible in [worlds containing closed timelike lines] to travel into any region of the past, present, and future, and back again, exactly as it is possible in other worlds to travel to distant parts of space'.[i]

So closed timelike lines are physically possible, in the sense that they are compatible with the equations of general relativity. But are there any in our universe? If not, is it possible for humans to manufacture them in our universe? These are open questions, and they have been vigorously debated in the physics journals in the past fifteen years. Several different sorts of time machine – that is, machines that can create closed timelike lines – have been proposed, and each proposal has met with numerous objections. No one has yet produced a practicable scheme for backward time travel in our universe, but nor has it been established that such a scheme *cannot* be produced. This is an open and exciting question in physics.

It is not our question here, however. It is not our job as philosophers to pronounce on these matters from the comfort of our armchairs. Rather, we shall focus on the alleged conceptual or logical problems with time travel.

The so-called paradoxes of time travel have played a significant role in both the physics and philosophy literatures. Many have claimed that time travel is logically or

conceptually impossible because they think the very idea of it implies a host of contradictions. If this is right, those physicists who are working on proposals for the construction of time machines are wasting their time, not to mention taxpayers' money. Ironically, even some of the most famous science fiction writers have taken this line. For instance, Isaac Asimov has written: 'The dead giveaway that true time travel is flatly impossible arises from the well-known 'paradoxes' it entails. … So complex and hopeless are the paradoxes … that the easiest way out of the irrational chaos that results is to suppose that true time travel is, and forever will be, impossible.'[ii] But do these alleged paradoxes really carry any weight at all?

The 'no destination' objection

Let's start with what has been called the 'no destination' objection to time travel. (Note: this isn't one of the official paradoxes of time travel, but it's surely an objection that many people will have in mind.) We said earlier that genuine time travel requires that one literally go to the past or future. This implies that the past and future exist. You can't travel to or from a nonexistent place or time. So it seems that time travel is possible only if the past and future exist. But on the most common or ordinary view of time, the past and future *don't* exist. Only the present is real. The past did exist, but it's now, and forever will be, inaccessible to us. It's gone, settled, closed. The future will (may) exist, but it doesn't exist yet. It's open in the sense of being a realm of many possibilities, none of which are as yet determined or determinate. If this conception of time is correct, there's nowhere or nowhen for a time-traveller to go to or to come from.

For time travel to be possible, we need a different conception of time: four-dimensionalism. Other times are like other places. Other places aren't here; they're somewhere else. But that doesn't make them less real than Wellington. They're simply at a spatial distance from us.

Similarly, other times (past and future) aren't now: they're somewhen else. But that doesn't make them less real than the present. They're simply at a temporal distance from us. Our ancestors and descendants exist just as much as we do and in the same full-blooded sense. They're just at a temporal distance from us. We often *think* that the present is special, that what's happening now is really real, but this feeling is simply a reflection of our limited cognitive access to all of what exists.

(It's worth noting here that this picture is perfectly orthodox in physics. It's not a crazy view that philosophers have cooked up just to make room for time travel.)

Time discrepancy paradoxes

Suppose a time traveller gets into her rocket and flies off along a closed timelike line. Her journey lasts one year, and she ends up 65 million years in the past. She lives out her life in the past, dying at the age of 95, over 64 million years before her birth. But surely this

is absolute nonsense? How can the time traveller traverse 65 million years in one year; and how can she die at the age of 95, roughly 65 million years *before* she is born? These are straightforward contradictions. The basic description of what backward time travel involves is incoherent. Therefore backward time travel is impossible.

Note that this sort of problem also arises in the case of forward time travel. The forward time traveller traverses 65 million years into the future in one year; and she dies at the age of 95, 65 million years after her birth. These are straightforward contradictions. Therefore forward time travel is impossible.

But hang on. Something must have gone wrong here, for forward time travel has *actually* occurred! What, then, is wrong with our objections to time travel?

Newtonian time – the time of Newtonian physics – is absolute and universal, the same in all reference frames. By reference to this time, all events can be objectively ordered, and the Newtonian universe can be divided into a series of universal instants. Relativistic physics, however, requires the rejection of this picture of time. The principle that the speed of light is constant makes no sense at all in the context of a fixed space and time. In relativistic physics there is no objective temporal interval between events. Different observers measure different intervals, and no unique one of them is right, with the others all being wrong. There is no privileged reference frame, hence no objective simultaneity, no universal Now.

Absolute time is replaced by time relative to a frame of reference. The *proper time* of an object is defined as the time relative to the frame of reference in which the object is permanently at rest. It is the time measured by a clock carried with the object.

The above objections to time travel dissolve when we see that the interval of time traversed by the time traveller and the duration of her journey – which, apparently paradoxically, have different magnitudes (65 million years and one year) – are measured with respect to different frames of reference. The 65 million years is measured with respect to that in which an Earth-bound observer of the time machine is stationary, the one year with respect to that in which the time traveller is stationary. The 65 million years is given in the observer's proper time, the one year in the time traveller's proper time. There is thus no reason why they should coincide.

The same goes for the discrepancy between the time elapsed since the time traveller's birth and her age upon her arrival. The former is measured with respect to the observer's proper time, the latter with respect to the time traveller's proper time. Finally, the same goes for the apparently paradoxical fact that the time traveller dies at the age of 95, roughly 65 million years before (or after) she is born. Her death occurs 95 years after her birth in her proper time, but 65 million years before (or after) her birth in the Earth's proper time. There is nothing contradictory or incoherent about that!

In two places at once?

For time travel to make sense to us, we need to employ a conception of a person that is different from the usual one. To see this, consider the following time travel paradox. If backward time travel were possible, it would be possible for a person to be in two (or more) places at once. For example, it ought to be possible for me to travel back and wish my younger self a happy 21st birthday. But that's absurd! It's impossible for a person to be in two (or more) places at once. And so backward time travel is impossible**.**

This objection turns largely on a certain conception most of us have about a person. On the ordinary view, a person is a 3-dimensional object that moves along or with time. It is important to note that space and time are not treated in the same way in this conception of a person. A spatially extended object, such as the North Island, isn't wholly located at each of the places that constitute its spatial extension; only a *part* of it is. But a temporally extended object such as a person is thought to be wholly located at each of the times that constitute the person's temporal extension.

It *is* impossible for a person to be wholly located at different places at the same time. I can be partly in one place and partly in another, such as when I'm standing in the doorway between my lounge and kitchen; but I can't be wholly located in both the rooms at once. It's a mistake, however, to think that time travel implies such a thing.

The trick here is to think of ourselves as stretched out in time as well as space. Just as there's a part of me between my right knee and foot, there's a part of me between my 43rd and 44th birthdays. A person, on this view, is a collection of suitably related *temporal parts*. Strictly speaking, a person is never wholly located at any *one* time she exists. What's wholly located at any one time is a temporal part of the person, but no temporal part of a person persists over time. Some of my temporal parts are earlier than the part you see now, others (hopefully lots of them!) are later. Not all of them are present now. Backward time travel doesn't imply that it's possible for a person to be wholly located at different places at the same time. Instead, what it implies is that it's possible for *different* temporal parts of a person to be in different places at the same time. That is precisely what would happen if I were to travel back and wish my younger self a happy 21st.

Changing the past, or affecting it?

It's often thought that backward time travel would enable one to change the past in countless ways. One could go back and save the moa from extinction, one could prevent the *Wahine* from sailing on 10 April 1968, one could kill Hitler in his youth, and so on. But since it's impossible to change the past, that is, to make what *did* happen *not* to have happened (or vice versa), backward time travel is impossible.

It's a mistake, however, to think that backward time travel implies the ability to change the past. Of course, many science fiction stories involve time travellers *allegedly* changing the past, and by doing this they allegedly change the subsequent course of

history as well. Such stories may be entertaining, but they're logically incoherent. It's impossible to change the past (or future for that matter), for this amounts to saying, for instance, that Hitler both died in 1920 and did not die in 1920, which is a contradiction. The idea that backward time travel implies such a thing rests largely on the mistaken belief that times or events must be repeated if time travel is to occur, thereby giving a would-be time traveller a second go at them.

Suppose I'm about to enter a time machine and go back to 9 April 1968, the day before the *Wahine* disaster. Critics seem to think that the first time 9 April 1968 came around, I wasn't in New Zealand, and so I couldn't have done anything to prevent the sailing on the 10th. But they also seem to think that if backward time travel were possible, I could be there 'the second time around' and so could do something to prevent the sailing on the 10th, which is absurd.

For backward time travel to be possible, there need be only *one* 10 April 1968. There needn't be a second 10 April 1968, with a possibly different outcome the second time around. We're not denying that one could legitimately speak of times or events being repeated. But it would still be a mistake to think that this would enable a time traveller to change the past. [no new para here]Some time travel stories rely on the idea of parallel or branching universes. While this may provide a sense in which times or events can occur more than once, it won't give us a case in which a time traveller can change the past. Why? Well, in *our* past the *Wahine* did sink on 10 April 1968. Suppose a time traveller were to go to a second or different time-series or universe, to a *second* or different 10 April 1968. If there is no sinking of the *Wahine* on that day, whether or not it's the result of a time traveller's actions, the time-traveller hasn't changed *that* universe's past. Nor has the time traveller changed our past.

Backward time travel doesn't imply that it's possible to change the past. It does, however, imply that it's possible to *affect* or influence it. Thus, for example, the time traveller's setting various controls at one time (partially) causes her arrival at an earlier time. But a complete, accurate chronicle of her destination time would tell of her arrival *before* her departure. Her actions have an effect on earlier events, but they don't change them. [no new para here]It's not as if a time traveller wasn't in Wellington on 10 April 1968 and then a second time around is there. If a time traveller is going to travel back to some past time, she *has already been there*. And if she is going to do something when she gets there (such as save a life), she *has already done it*.

The Grandfather paradox

So far we have seen no reason to suppose that backward time travel is logically or conceptually impossible. But we have not yet considered the big objection: the Grandfather paradox, (a variant of which is known as the auto-infanticide paradox). The objection is that if backward time travel were possible, then there would be nothing to stop a person travelling back in time and killing his grandfather before his grandfather had a chance to produce offspring. But then the time traveller himself would not be born,

and this is a contradiction: the time traveller is both born (and grows up to make a time trip) and not born.

In fact, the time traveller does not have to go the roundabout route of killing his grandfather. He could go back into the past and kill his younger self, that is, commit auto-infanticide (or non-fatal suicide). But if he did this, then he himself would have died at a young age, and so not be there to kill his younger self. This is a contradiction: he is there and does the killing, but then he is not there doing the killing, for he died in his youth and never grew up to be a time traveller.

In sum, the argument is that if backward time travel were possible, there would be nothing to stop contradictions being true; hence, backward time travel is impossible.

This thought has led to some desperate moves on the part of science-fiction writers. Some of them suppose that magical Forces of Logic will arrest the time traveller's arm in mid-air as he raises his dagger to murder his grandfather. Others suppose that there are Time Lords or Guardians whose job it is to protect the past: these people spend their time going around ensuring that time travellers do not change the past. But these moves are unsatisfying. If it takes magical Forces of Logic or Time Lords to make time travel possible, then time travel may as well be *im*possible. There are no Guardians and no mysterious Forces of Logic, so there will not be any time travel, if these are what time travel requires.

But is it really true that if backward time travel were to occur, and if there were no Time Lords or mysterious forces, then contradictions would hold? Killing one's younger self is impossible. Does this mean we need to posit special things to prevent it from occurring? Surely the mere fact that it is impossible is enough! If your friend tells you he is off to square the circle, or prove that the square root of two is a rational number, you do not frantically dial the Logic Police to come and stop him. You know that he will fail, and there is no real mystery about how or why he will fail.

The same is true of time travellers! The time traveller cannot kill his younger self. That is as impossible as eating oneself right up until there is nothing left (starting from the feet up), or proving that 1=2. So what stops the time traveller killing his younger self? Well, any or all sorts of mundane things: he slips on a banana peel as he goes to push his younger self under a bus; he forgets to mix oil into the petrol for his chainsaw and the chainsaw seizes up; the phone rings and startles him as he is about to pull the trigger of his sniper rifle; he is killed by a mad man who thinks (mistakenly) that the time traveller is *his* grandfather; and so on. Nothing special is required to prevent impossible things happening. They *cannot* happen, so their not happening looks after itself!

Thus, nothing extraordinary is required to prevent time travellers from changing the past. They cannot do it – no one can – and so, even if they have time machines, they will not do it—and no special mechanisms are required to explain their failure. Time travel would not open the way to contradictions, even in the absence of Time Lords and magical

forces. Hence, considerations of auto-infanticide do *not* show that backward time travel is impossible.

Where are the time travellers?

So far we have looked at arguments that aim to show that time travel is impossible: that it cannot occur. Suppose we are right in claiming that these arguments do not carry weight. Even so, it might seem that we have conclusive reason to believe that backward time travel will not occur. For if backward time travel is going to occur, then we would already have encountered the time travellers involved. No time travellers need have departed yet, if time travel has not yet been perfected, but some would have arrived before now, and we would know about it. But we know no such thing. We have not encountered any travellers from the future, and hence we know there will never be any backward time travel.

Can we maintain that backward time travel might actually occur, even if we agree that we have never seen any travellers from the future? We can. Suppose that time travel will involve the *manufacture* of closed timelike lines by humans. According to most of the theories discussed in the physics literature, it is not possible to create a closed timelike line that gives one access to times prior to the creation of the closed timelike line. Thus, the fact that time travellers have not visited *us* does not mean that no one will ever travel into their own past.

What about naturally-occurring closed timelike lines, as opposed to ones manufactured by humans? Can we at least conclude that there are none of these, because if there were, we would have seen time travellers emerge from them? No, we cannot.

The issue here is similar to the issue of whether if there were extra-terrestrial life forms, we would have encountered them. If there were a great deal of extra-terrestrial life not far from here, then we would expect to have encountered some of it. But the fact (if indeed it is a fact) that we have not yet encountered any ETs leaves open the possibility that there might be plenty of extra-terrestrial life located far away from us, whether in space or time.

Similarly, all we can conclude from the fact, if it is one, that we have not encountered travellers from future civilisations on Earth is that there are probably not a lot of closed timelike lines in our universe which end up near the Earth in the recent past, start near the Earth at a time at which the technology will be available to exploit them, and do not take prohibitively long to traverse. This still leaves plenty of room for time travel.

Finally, even it is true that time travel will never occur, this does not necessarily show that time travel is particularly problematic. It may simply be the case that humans become extinct before time machines are perfected!

Our conclusion is that none of the arguments we have considered here shows that time travel is impossible.

Further reading

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[i] 'A Remark About the Relationship Between Relativity Theory and Idealistic Philosophy' in P.A. Schilpp (ed.) *Albert Einstein: Philosopher-Scientist, Vol. II* (*Library of Living Philosophers, Vol. VII*) Evanston, IL, 1949, p.560.

[ii] 'Time-travel' in *Asimov's Science-Fiction Magazine* April 1984 (cited in Nahin, p.27).