Paradoxes of causal loops in spacetime

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Abstract

There is, among some scientists and philosophers, the idea that any theory that would allow the time travel would introduce causal issues. These types of temporal paradoxes can be avoided by the Novikov self-consistency principle or by a variation in the interpretation of many worlds with interacting worlds. The world in which we live has, according to David Lewis, a Parmenidean ontology: "a manifold of events in four dimensions," and the occupants of the world are the 4-dimensional aggregates of the stages - "temporal lines". The causal loops in backwards time travel involve events that appear to "come from nowhere," paradoxical "self-existent" objects or information, resulting in a bootstrap paradox. Many believe that causality loops are not impossible or unacceptable, but only inexplicable.

Keywords: paradoxes, causal loops, spacetime

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There is, among some scientists and philosophers, the idea that any theory that would allow the time travel would introduce causal issues. (Bolonkin 2011) These types of temporal paradoxes can be avoided by the Novikov self-consistency principle or by a variation in the interpretation of many worlds with interacting worlds. (Everett 2004)

The classic argument against backward causality is the *bilking argument*. (Horwich 1987) If an event A causes a previous event B, bilking recommends an attempt to de-correlate A and B, that is to bring A in cases where B did not occur and prevent A in cases where B occurred.

A causal loop is a sequence of events (actions, information, objects, people) (Lobo and Crawford 2002) where an event A causes another event B, which determines the first event A. (Rea 2014) At such events in spacetime their origin can not be determined. (Lobo and Crawford 2002) Events that form a loop must not be the complete causes of each, nor the complete effects of another. In a causal loop there may be secondary causes or external events. If there are no such causes or events, it is said that the loop is *causally isolated*.

Backward causality presupposes a closed ontological future - a metaphysical time position usually called eternalism, a specific form of non-presentism. (Faye 2001)

Backwards time travels determine causality loops? Hanley (Hanley 2004) asserts that there can be a backward time travel and a reverse causality without any causal loops. (Hawking 1992) Monton (Monton 2009) criticizes Hanley's example but agrees with his statement.

The world in which we live has, according to David Lewis, a Parmenidean ontology: "a manifold of events in four dimensions," and the occupants of the world are the 4-dimensional aggregates of the stages - "temporal lines". (Lewis 1976) However, the time traveler is not like other aggregates; "If he travels to the past it is a zigzag line." (Lewis 1976) There may also be broad lines that are travels in the future. This Parmenidean world of temporal stages immediately removes the "no destination" objection to the time travel. Four-dimensional geometry provides the means to record the travel of the time traveler.

Many believe that causality loops are not impossible or unacceptable, but only inexplicable. There were two main types of response to this objection. Lewis (Lewis 1976) accepts that a loop (as a whole) would be inexplicable, such as Big Bang or the disintegration of a tritium atom, but it is just strange, not impossible. Similarly, Meyer (Meyer 2012) argues that if someone asks for an explanation of a loop (as a whole), the fault would fall on the person who asked the question, not on our inability to answer. Another answer, Hanley, (Hanley 2004) is to deny that (all) causality loops are inexplicable. Mellor (Mellor 1998) believes that in such loops the chances of events will not be related to their frequencies, according to the law of the large number. Berkovitz (Berkovitz 2001) and Dowe (Dowe 2001) argue that Mellor fails to establish the impossibility of causality loops.

The causal loops in backwards time travel involve events that appear to "come from nowhere," (Smith 2016) paradoxical "self-existent" objects or information, resulting in a *bootstrap paradox*. (Toomey 2007) A time traveler who steals a time machine from the local museum to make a journey in time and then give the machine same time to the same museum at the end of the travel (that is, in the past); in this case, the car itself is never built by anyone - it simply exists. (Everett and Roman 2012) Everett gives an example of an *informational paradox*: a time traveler copies a mathematical demonstration from a manual, then travels back in time to meet the mathematician who firstly published the demonstration, the mathematician simply copied the demonstration at one time before the publication, in which case the information in the demonstration had no origin. (Everett and Roman 2012) Or an *ontological paradox*: (Smeenk and Wüthrich 2011) Kelley L. Ross (Ross 2016) gives the example of a physical object whose world line or history forms a closed loop over time where there may be a violation of the second law of thermodynamics: a clock is given to a person, and 60 years later the same clock is brought back in time and given to the same person. Ross states that the entropy of the clock will increase, and the clock transmitted back in time will be more worn out with each repetition of its history.

Andrei Lossev and Igor Novikov have named such objects without origin *Jinn*, with the singular term *Jinnee*. (Popper 1985) An object that makes the circular passage through time must be identical whenever it is returned to the past, otherwise it would create an inconsistency.

Krasnikov writes that these paradoxes always involve a physical system that evolves at a stage in a way that is not governed by its laws. He does not find this paradoxical and assigns the problems regarding the validity of the time travel to other factors in the interpretation of general relativity (Krasnikov 2002)

General relativity allows some solutions that describe universes that contain closed timelike curves, or world lines that lead to the same point in space. (Gödel 1949) Igor Dmitriyevich Novikov said about the possibility of closed timelike curves (CTCs) that only self-regulatory travels would be allowed. (Novikov 1983) He suggested the *principle of self-consistency*, which says that *the only solutions to physics laws that may appear locally in the real universe are those that are self-consistent at a global level*. Novikov's opinions are not widely accepted. Visser sees the causal loops and Novikov's self-consistency principle as an ad-hoc solution and assumes that there are far more detrimental implications of time travel. (Nahin 1999) Krasnikov finds no inherent fault in the causal loops but finds other problems with time travel in general relativity. (Krasnikov 2002)

Ulrich Meyer states that saying causality is mysterious is to say that it is always inexplicable, and he do not think it is right. The causality curves may admit all the explanations that they might reasonably require. (Meyer 2012) Asking for all events, including those in the causal loops, to be explicable, is to support Leibnitz's *principle of sufficient reason* (PSR)[1], but there are different ways of understanding this principle, such as PSR reading as a causal principle: (Meyer 2012).

One version would be that *each event has a sufficient reason*, PRS1, (Schlesinger 1995) which implies inference at the best explanation. This version often leads to infinite chains of events where each event is caused by the previous, *ad infinitum* (such as standard classical mechanical models where all events at a given moment are caused by events from a previous time, which, in turn, are caused by events at a previous moment, and so on), (Meyer 2012) also valid for causal loops. PRS1 requires that each event has a causal explanation, not that the chain of explanations ends somewhere. But PRS1 is not exactly what Leibniz had in mind when he developed the principle of sufficient reason in *De rerum originatione radicali* (1697):

> "Let us imagine that the book of the elements of geometry has always existed, one always copied from another; it is evident that, even if a reason can be given for the present book from a

[1] The principle of sufficient reason states that everything must have a reason, cause or motive. (Rescher 1991)

past one, from which it was copied, nevertheless we shall never come upon a full reason no matter how many past books we assume, since we would always be right to wonder why such books have existed from all time, why books existed at all, and why they were written in this way. What is true of books is also true of the different states of the world; for a subsequent state is in a way copied from a preceding one (although according to certain laws of change). And so, however far back you go to earlier states, you will never find in those states a full reason why there should be any world rather than none, and why it should be such as it is." (Leibniz 1956)

By its very nature, a complete reason could not be a causal reason and would therefore overcome what is in question in PRS1.

The second interpretation of the principle is: *There is a sufficient reason why the whole world is as it is* (PRS2):

"... we might be able to explain the existence of a time machine at t_1 in terms of the existence of a time machine at t_2, but thisdoes not appear to explain why there is a time machine at all. But if we take this worry seriously then we should also worry about, say, why it is that there are electrons. We can easily explain this causally, in terms of the laws of nature and the fact that there were electrons 5 minutes ago. But then the question arises why those earlier electrons existed, and we are quickly led into an infinite regress of causal explanations that never succeed in giving a full reason for why there are any electrons at all." (Meyer 2012)

PRS2 has the undeniable consequence of excluding contingent truths, resulting that PRS2 "is false and that requests for full explanations are misguided." (Meyer 2012) It follows that if the laws of nature co-operate, then the events that form a loop can be explained causally. Asking for a more detailed or "complete" explanation of the causal loop is asking for something that is impossible. "In this case, the blame would fall on the person asking the question, not on our inability to answer it." (Meyer 2012)

Causal priority (certain sequences of related events) may be different from temporal priority (total events). If the cause was later than the effect, then the cause should be unstoppable. But, in general, we can intervene in the world to provoke or prevent contingent incidents. If the cause of an event is in the future, then such interventions are subject to clear constraints, and in some cases it will prove impossible. (Grey 1999)

Simon Keller and Michael Nelson (Keller and Nelson 2010) state that there is no premise of a preferential specificity involved in any argument, so that there is no special issue for time travel in terms of presentism.

Wheeler and Feynman (Wheeler and Feynman 1949) were the first to argue that the fact that nature is continuous does not involve causal paradoxes.

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