THESIS

ON COINCIDENCE IN CAUSAL LOOPS

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ABSTRACT

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The existence of closed time-like curves in Gödel's solutions to Einstein field equations would allow for the physical possibility of backward time travel. Since Gödel's publication in 1949, philosophers have examined the logical constraints surrounding the possibility of backward time travel. A popular objection to this claim, known as the autoinfanticide paradox/grandfather paradox, holds that if backward time travel were possible, then it would be possible to travel back in time and kill one's younger self or prevent their birth from ever occurring. Authors such as David Lewis (1976) have responded to the autoinfanticide objection by arguing that attempts by time travelers to kill their younger selves would result in "coincidental events" such as gun jams and banana slips, which prevent such autoinfanticide attempts from succeeding. Paul Horwich responds to Lewis in his book *Asymmetries in Time: Problems in the Philosophy of Science* by arguing that such coincidences would be improbable. In this paper, I will argue that Horwich's improbability in describing these coincidental events is misguided due to the failure of the frequency principle. Utilizing Berkovitz's response in his paper "On Chance in Causal Loops," which responds to Mellor's argument for the impossibility of causal loops from his book “Real Time II”. I will show that the frequency principle fails due to the frequency of events in causal loops always having biased reference classes.

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CHAPTER 1

1.1 Introduction

Kurt Gödel's (1949) discovery of certain solutions to the field equations of general relativity permits the existence of closed causal chains. This Gödelian spacetime implies the possibility of backward time travel into the local past. A popular objection to this claim, known as the autoinfanticide paradox, holds that if backward time travel were possible, then it would also be possible to travel back in time and kill one's younger self or prevent their birth from ever occurring. Authors such as David Lewis (1976) have responded to the autoinfanticide objection by arguing that attempts by time travelers to kill their younger selves would result in "coincidental events" such as gun jams and banana slips, which prevent such autoinfanticide attempts from succeeding. Paul Horwich (1987) classifies these autoinfanticide cases as bilking attempts, arguing that even though backward time travel is not impossible, the coincidence solutions to these bilking cases show backward time travel to be improbable.

In this paper, I will argue that the improbability attributed to these coincidental events is partially due to the failure of what is known as the frequency principle. This principle dictates that the chances of effects with and without their causes constrain long-run unconditional frequencies (Mellor 1998). I will argue that the improbability Horwich attributes to these coincidental events is misguided. Utilizing Berkovitz's argument against Mellor in his paper "On Chance in Causal Loops," which shows that the frequency principle fails in causal loops due to reference classes always being biased, I will show that these coincidental events have a determinate frequency of occurring.

The first section of my paper will illustrate the concepts of chance and frequency used by Mellor and Berkovitz before examining Mellor and Berkovitz's arguments for why the frequency principle fails within causal loops. In the next chapter, I will begin by examining the bilking argument and the autoinfanticide objection and why they present a problem for the possibility of time travel. I will then argue that these coincidental events, which foil bilking attempts from succeeding, have biased reference classes that necessitate their occurrence. In my last chapter, I will draw out Horwich's argument for the improbability of these coincidences and time travel in his 1987 book *The Asymmetries of Time* and his 1975 paper "On Some Alleged Paradoxes of Time Travel." I will then examine Phil Dowe's reformulation of Horwich's argument, allowing us to examine Horwich's use of correlation and improbability in the context of Berkovitz and Mellor. Lastly, I will argue that Horwich's notion of these coincidences as improbable fails due to the failure of the frequency principle.

1.2 Chance and Frequencies

Within the philosophy of probability, the concept of chance remains unclear as discussions of its role and existence are still being debated. The most standard view holds that chance is a process notion of objective probability that ascribes a value between zero and one to the occurrence of an event. For example, a fair coin flip has a .5 chance of landing heads and a .5 chance of landing tails. Thus, we are saying it is possible for the coin to land heads, and the likelihood of the coin landing heads is equal to the likelihood of it landing tails. In contrast, if an event has an objective chance of either one or zero, its occurrence would either be determinate or impossible.

What gives these possible outcomes their chances? The debate on this question mainly falls into two camps: subjective and objective chance. Subjective chance ascribes chances with one's credence of belief. Under subjective chance, a perfectly rational actor with all the relevant information on the likelihood of a possible event's credence of belief would ascribe the chance to that event. For this paper, we will focus on the objective notion of chance. Objective chance takes a chance to be instantiated in physical reality. This means that when we say the coin flip has a .5 chance of landing heads, we are making a statement that is made true or false by virtue of real-world facts.

Some objective chance theorists, such as Mellor (2000), take chance statements to have truthmakers, which are the properties of facts that make up the causal process of the event. For example, the .5 chance of the coin landing heads is a property of all the relevant facts, such as the flip, the coin, the person flipping the coin, etc. It is important to note that events can still be ascribed indeterminate chances even when we know the outcome. This is due to objective chances being based in an event's process rather than its outcome. For example, we know a coin can only land heads or tails, which would dictate a determinate probability of either 1 or 0 for the possible outcomes. Chances are given to events because of all the relevant facts that make up the process. For example, if you looked into the future and knew before you flipped it that the coin would land heads, what would the chances be that the flip would land heads? One might think that the chance would be determinately one as that is what will happen (this would be correct under a subjective credence view). But the key is that the outcome has not occurred yet. At the time of the flip, when the chance is ascribed, the outcome only exists in the future. The statement “the coin landing heads has a chance of 1” cannot be made true since its truthmaker (the coin landing heads) does not yet exist. Therefore, we must say the coin still has a .5 chance of landing heads even if we know landing heads will be the case. (Mellor 2000)

There is no possible world in which one can go back in time and kill one's infant self, and this impossibility is not physical; it is metaphysical. One is physically capable of committing autoinfanticide; there are no laws of nature or physical constraints that prevent such actions from taking place in the past. Rather, such auto-infanticide attempts are metaphysically impossible in virtue of all possible worlds and their histories being internally consistent. To change the past or to bilk a sequence of events would entail contradictions that would violate this consistency. We can now begin to approach the issue at hand, which partly motivates the coincidence solutions we are discussing. According to authors such as Effingham (2020) and Horacek (2005), metaphysically impossible events can have positive chances. Why is this the case? If objective chances measure the likelihood or the possibility of a given event occurring, then why is it that events we know to be impossible have positive objective chances instead of a determinate chance of zero?

We can begin answering this question by examining an example of a coin flip in a causal loop. In this example, a coin is found heads up and flipped; when the coin is flipped, it travels back in time and lands in the place where it was originally found. We can break this example into the following set of events: Event A: a coin is found heads up, Event B: the coin is flipped, Event C: the coin travels back in time, landing heads up where it was found (Figure 1).

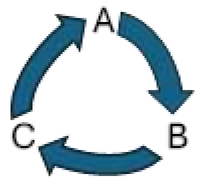

Figure 1.

If we say the coin flip is fair, then we can say that the flip has a .5 chance of landing heads or tails. That is, the event of the coin traveling back in time to where it was found would still have a .5 chance of landing heads or tails. In this example, even though we know it to be the case that the coin will land heads, and it is metaphysically impossible for it to land tails as that would be a change to the past (since it was found heads up), we can still assign a positive chance of .5 to both events occurring due to chance being based in physical possibility rather than metaphysical possibility and its process rather than outcome dependence. In a normal coin flip (linear causation), it is a physical possibility that the coin can land either heads or tails. The addition of time travel, the knowledge of the outcome, and the metaphysical impossibility of the coin landing tails does not make our coin flip different in any physical sense to the one in normal causation, as it is just as physically possible for the coin to land tails in both cases. Chances being based on physical possibility is only one of the reasons why these metaphysically impossible events have positive chances. As mentioned previously, chance being a process rather than an outcome theory of probability also motivates this ascription of positive chances. Horacek (2005) gives another example to further elucidate our intuitions on the matter. He asks, "What are the chances that Tom, a permanent bachelor, will get married?" He states there are two ways to answer this question. The first holds the chances of Tom getting married in conjunction with the fact that Tom is a permanent bachelor, which would result in a chance of zero since no permanent bachelor can get married. The other way, which Horacek holds to be the correct view, takes the chances of Tom getting married to be determined by "the laws and worldly conditions"—things such as Tom's looks, personality, and motivations. The fact that Tom *is* a permanent bachelor or that the coin *will* land heads, Horacek takes to be irrelevant to the chances. They are facts about future outcomes which have no influence on the chances of present events.

While the literature tends to agree on this view of chance in nonlinear causation, this paper will look at some implications of this view of chance concerning relative frequencies in nonlinear causation.

To illustrate the concept of relative frequency, consider a study where, out of the thousand daily smokers participating in the study, a hundred were found to have developed cancer. It was concluded that daily smokers have a .10 relative frequency of developing cancer[1]. A relative frequency measures the given occurrence of an event (cancer) within a reference class of events (daily smokers).

Frequencies show us correlations between events; in our case, daily smoking and cancer. A Humean account of causality is skeptical of our ability to know or observe the necessary causal links between connected events. Instead, this view holds that causal relations are merely the constant observation of two events occurring together. In our case, this would suggest that the frequent co-occurrence of cancer in daily smokers is what we interpret as a

[1]This example is fictious but is used to help illustrate the concept of frequencies.

causal relationship between smoking and cancer.[2]. As we can see, it is not the case that every daily smoker develops cancer, so to say smoking causes cancer may be too strong a causal connection to draw from the observation of frequencies. It would seem more apt in our case to say that daily smoking raises the likelihood of developing cancer. However, frequencies are clearly related to our understanding of chance and probability, which we'll explore next. To ascribe a chance to an event is to speak on the likelihood of its occurrence in actuality. If one were to say there is a .10 chance of developing cancer given daily smoking, then one would expect that in one out of every ten daily smokers, there would be a development of cancer. This is often the connection made between chance and relative frequencies: an expectation of likelihood that is representative of what takes place in reality.

To ascribe an objective chance to an event's occurrence is to claim a fact about the way the world is. The question of what makes these probabilistic facts about the world true remains an open question. An objectivist theory of chance holds that there exists a truthmaker—something that exists in reality that makes these facts about chance true. Relative frequencies currently act as one good candidate for these truthmakers, these types of claims often fall into what are known as frequentist views of chance. It does seem to follow, however, that some type of relation exists between objective chances and their relative frequencies. The most basic claim being that these frequencies provide evidence for the truth of chance statements, and similarly true chance statements give evidence as to what their relative frequencies will be.

[2] "Exactly what conclusion Hume drew from this is still disputed, but one very influential interpretation of his thought is that he believed therefore that causation was in reality nothing more than the constant conjunction of two types of event" (Handfield, 2012, p. 104).

While there is little disagreement that there exists some type of relationship between relative frequencies and chances, the frequentist theory of chance takes this a step further in claiming chances to be frequencies[3]. Frequentists make the identity claim that chances can be reduced to their relative frequencies. There exists two accounts of frequentism: actual and hypothetical frequentism. Actual frequentism takes the chances of a given event to be the relative frequency of that event's occurrence in a finite number of real-world cases, whereas hypothetical frequentism takes the chances of an event to be the frequency of that event given a hypothetically infinite number of cases. Hypothetical frequentism results in what's known as long-run frequencies, the occurrence of events given an infinite sequence of events of the same type[4]. For example, if we were to suppose an infinite number of cases in which a certain event may occur and in half of these cases this event occurs resulting in a long-run frequency of .5, the hypothetical frequentist would ascribe a chance of .5 to that event's occurrence. The fundamental distinction between these two forms of frequentism lies in the scope of the reference class: Finite and actual in one case, infinite and hypothetical in the other, a difference that has significant implications for how we interpret chance.

Relative frequencies are always defined within a reference class—the particular events to which we ascribe chances and frequencies are always considered within a set of circumstances. The grouping of a type of event under similar circumstances forms what is known as a reference class (Handfield, 2012, p.106). For example, imagine Tom has a fair coin

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[3] Frequentism is often referred to as Actualism, and Humean Reductionism.

[4] For more on hypothetical verses actual frequentism see SEP entry on *Interpretations of Probability,* Section 3.4 Frequency Interpretations.

and wants to determine the chance of the coin landing heads when flipped. Tom observes that in all coin tosses ever recorded, half land heads. Here, we have a frequency of 0.5 for a coin landing heads when flipped. This frequency falls within the reference class of all coin flips that have ever occurred. But the question arises: how do we ascertain that this frequency is in the appropriate reference class? One could instead choose to use the reference class of coin flips by people named Tom, or even more narrowly, coin flips made solely by this specific Tom.

The difficulty in determining the correct reference class for a given relative frequency is known as the reference class problem, a significant objection to the frequentist view[5]. If an objectively correct chance exists that corresponds to a relative frequency, then that frequency must belong to a specific reference class. It's plausible to argue that the initial reference class of 'all coin flips' is excessively broad. Overly broad reference classes can obscure relevant similarities among the events in question. For instance, if a student wants to know their chance of failing a physics exam, looking at the frequency of students failing *any* exam at their university would be unhelpful. In this case, the reference class fails to capture the specific information sought (the chance of failing this particular physics exam). A narrower reference class, such as the frequency of failures in exams given by this specific professor, would offer more relevant and precise information for the student. However, employing narrow reference classes can also create issues in capturing relevant information. If one considers the narrowest possible reference class for any event, it might contain only that single instance of the event. This would result in a frequency, and consequently a chance, of either one or zero. Such an

[5] For further details on the Reference Class Problem see Chapter 7 (Actualist Theories of Chance)- of Handfield's book *A Philosophical Guide to Chance.*

extremely narrow approach also fails to provide the kind of information we seek. While the tenability of the frequentist view remains debatable, primarily due to the reference class problem and other challenges in reducing chance to frequency, the connection between frequencies and chances is undeniable.

1.3 Propensity

While the frequentist view faces challenges due to its identity relation between chance and frequency, propensity theories have gained wider acceptance in contemporary discussions of chance and probability. Similar to frequentism, propensity theorists consider objective chances to be instantiated in physical reality, rather than being purely epistemic. However, instead of equating chances with frequencies, they conceive of chances as physical propensities of a situation to produce a particular outcome. Although the origin of propensity theories is often attributed to Karl Popper, Charles S. Peirce is recognized as the first to anticipate such a theory, describing probability as the "would be" of an object to produce a particular frequency of outcomes given an infinite series of trials (Berkovitz, 2015, p. 630). Propensity theories are commonly divided into two categories, based on whether these propensities are characterized in terms of single cases or long-run frequencies. Single-case propensity theories hold that each setup or trial has propensities to produce a specific outcome. These theories are further subdivided into dispositional and tendency theories. Tendency theorists, like Popper (1959), view probability as a *tendency* of a single case to produce a specific outcome—for example, the tendency of a particular die to land on six. Dispositional theorists, such as Mellor, consider propensities to be *dispositions* of a single case to produce a probability distribution over multiple outcomes. For example, the disposition of a die to produce a distribution of 1/6 for each face. In contrast to single-case propensity theories, long-run frequency propensity theorists define probability as the propensity of a set of circumstances or trials to generate a frequency of a given outcome when repeated. Similar to single-case propensity theorists, long-run frequency propensity theorists can be further divided according to whether the frequency results from a finite or infinite number of repetitions (Berkovitz, 2015, p. 630). The variety of propensity theories, particularly the debate between single-case and long-run interpretations, highlights the ongoing complexity in our understanding of chance and probability.

Mellor's theory of chance follows from two accounts of chance as single-case propensities. In his 1995 book "*The Facts of Causation"* Mellor's first account of chance, known as modal chances, argues that "Modal chances measure a contingent and quantitative kind of possibility, and the degrees of possibility they measure are reflected in the hypothetical infinite limiting frequencies that these chances entail." (Berkovitz, 2015, p. 655). In later work, however, Mellor gives a somewhat different account of chance from this earlier version, which takes chances to be dispositions of circumstances to yield infinite limiting frequencies rather than contingent possibilities.

For this section, we will focus on Mellor's earlier modal account of chance, as this seems to be the basis of his argument against the possibility of causal loops. Under this account, Mellor takes the chance of a given event to occur to be a property of some other fact or set of facts. Mellor argues that chances are properties that meet the necessity, evidence, and frequency conditions:

> "That is, let Q and P be particular instances of facts of kinds Q* and P*, respectively, fn(P*) be the frequency of P* in series of length n and f ∞ (P*) be the limit of fn(P*) as n approaches infinity, ch(P) = p be the single case chance of P being p, and cr(P) be one's credence, i.e. one's epistemic probability of P. Then, every ch(P) = p that

is a property of a fact Q entails that:(Necessity) If p = 1, P is a fact; (Evidence) If ch(P) = p is one’s evidence about P, then cr(P) should be p; (Frequency) Any collective of facts of a kind Q* with the property ch(P) = p will have the limiting frequency $f_{\infty}(P^*) = p$.”
-(Berkovitz, 2015, p.667).

The necessity condition holds that if the chances of P are determinately 1, then P is a fact put in terms of event causation. If the chances of a given event's occurrence are one, then it is necessary that the event will occur. The evidence condition holds that there should be an equivalency between one's subjective credence and the known evidence of the objective chances. Lastly, the frequency principle, which we will discuss in further detail in a later section, holds that there lies an equivalency between the chances and frequency of a given event's occurrence.

From this basis, Mellor argues for his view of causation, which takes a cause to have a propensity to yield its given effect. This propensity is represented by what he calls closest world conditionals with chancy consequences. This means that given a cause X, we can measure the chance that its effect Y occurs by the strength of the propensity of X to yield Y. However, Mellor notes that the chances of effect Y with its cause X is a property of a given set of circumstances Z. Therefore, cause X can only be a partial cause of Y. The full cause of Y is both cause X and circumstance Z. This full cause is what he takes to have the propensity to yield an effect. In the following section, we will explore another aspect of this connection: the relationship between chances and their long-run frequencies, drawing on the frequency and conditional frequency principles from Hugh Mellor's book Real Time II.

1.4 Impossible Frequencies

Within the philosophical study of time, the entities known as past, present, and future have divided the field of study into two camps. A-theorists argue for what's known as the A-series conception of time, which orders events in terms of past, present, and future. This is in opposition to the B-series conception of time, a view held by B-theorists that takes time to be the ordering of events based on them being prior and posterior to one another. In his book Real Time II, Hugh Mellor considers this debate's key question: "What makes a statement like 'e is past' true when it is true, namely at any time later than e?"[6]. He claims that A-theorists such as McTaggart view these terms of past, present, and future as properties that are instantiated in events. The event has the property of "being past," so it would be true to say such an event is past. Mellor's view holds that these properties don't exist; rather, it is an event's relation to a particular time that orders it as past, present, or future. For example, if the event of my lunch took place at noon, then my statement the following evening, "lunch is past," would be true, not in virtue of lunch having the property of being in the past, but rather because when the statement was made that evening, the lunch would indeed have been prior. The event of 'lunch' is only past in virtue of it being prior to 'evening,' the time at which the statement was made. If the same statement were made in the morning, it would be false since the event is no longer before the time at which the statement was made.

While the meat of Mellor's *Real Time II* focuses on arguments that motivate his B-theory of time against A-theorists like McTaggart, the last chapter of his book Mellor examines nonlinear time and causality in the form of cyclical time, backward causation, and causal loops.

[6] (Mellor,1998,p. 2) The use of 'e' refers to any given event.

The existence of nonlinear time and causality presents significant issues for B-theorists such as Mellor, who require a linear conception of time. To sustain his view of linear time, Mellor works to disprove the existence of such causal occurrences that would pose substantial issues for his B-theory of time. In chapter 12 of his book, Mellor presents his argument for the impossibility of causal loops. The following sections will cover Mellor's argument in detail, exploring Mellor's metaphysical framework, which will cover his theory of chance, independence of causal facts, frequency principle, and conditional frequency principle.

1.5 Mellor's Metaphysical Framework

In *Real Time II*, Mellor must first draw out his conception of causality and chance before he can argue for the impossibility of causal loops. Mellor begins with his theory of causality, which takes time to be the causal dimension of spacetime. Under this view, the ordering of causes and effects gives time its linear direction. The possible existence of causal loops presents an issue for this linear view of causality as it would allow for effects to occur before and after their cause. Mellor begins by defining events in terms of particulars, which are defined as being identical if and only if they have the same causes and effects. He takes causation to link facts, the actual states of affairs, rather than particulars. However, as Berkovitz mentions, Mellor's argument can be framed in terms of either fact or event causation, and similarly to Berkovitz, I will be using event causation terminology interchangeably[7].

From here, Mellor moves on to his theory of chance, which we can use the following example to discuss more precisely. Suppose event A causes event B in circumstance S: A fair coin is flipped (event A), which causes the coin to land heads (event B) in a specific set of

[7] (Berkovitz, 2001, p. 11), On Chance in Causal Loops

circumstances (circumstances S). Mellor's theory of chance defines the chance of an event as a property of some other facts that satisfy the axioms of probability calculus. So, if event B (landing heads) has a .5 chance of occurring, this chance is a property of facts about event A as well as circumstance S, which include facts such as the velocity of the coin during the flip, the coin's mass, the hight of the flip, etc. These facts about the flip and the coin give the outcome landing heads its .5 chance of occurring. This implies, however, that as these facts change, chances will also change. Mellor grants that contingent events can have multiple chances at different times and that these chances don't have precise values. However, Mellor puts these complications to the side to facilitate his argument and assumes that chances have singular and accurate values: "An effect B has chances with and without its cause A. These chances are properties of all the relevant circumstances S in which A causes B" (Mellor, 1998, p.4). Applied to our example, we can say the chances of the coin landing heads with and without it being flipped are properties of all the relevant circumstances in which the coin is flipped. Mellor frames these chances in terms of closest worlds: "the chances of B in the closest S&A and S&-A worlds." Furthermore, Mellor uses the denotation of A*, B*, and S* to represent events of type A, B, and circumstances S. So, while 'event B' denotes the singular particular of a coin flip landing heads, 'B*/B type events,' would denote all the events in which a coin lands heads. Lastly, let "F" denote the long-run frequency of event types and "Ch" denote the chance of the event in its closest possible world.

Mellor assumes that in the long run, the chances of an event constrain the frequency of events of the same type due to the law of large numbers:[8] "the chance of a fact A in the circumstances S is p, then the long-run frequency of facts of type A in the same type of circumstances will almost certainly be p" (Berkovitz, 2001, p.7). This gives us the following equation:

1. $Ch_s(A)=P$ and $F_{s*}(A^*)=P$

Mellor believes that the chances and the long-run frequencies of events will maintain what is known as the "C*onditional Frequency Principle,"* given by the following two equations:

2. $F_{s*}(B^*/A^*)=Ch_{S,A}(B)$
3. $F_{s*}(B^*/-A^*)=Ch_{S,-A}(B)$

The conditional frequency principle relates closest-world chances to long-run conditional frequencies. $F_{s*}(B^*/A^*)=Ch_{S,A}(B)$, for instance, says that the long-run frequency of the of B-type events in the class of A-type events in S-type circumstances is equal to the chance of event B in its closest S and A worlds (chance of event B in the closest possible world where event A has occurred in circumstances S). In applying this to our example, we can say that the long-run frequency of all the events in which the coin lands heads, in the class of events in which both the coin is flipped and the relevant circumstances are maintained, will be equivalent to the chance that the coin will land heads given the closest possible world in which both the coin is

[8] The terminology used by Mellor would seem to imply something close to a hypothetical frequentist view. But rather than taking chances to be identically equivalent to their hypothetical long run frequencies, He instead draws a relation between the two concepts by taking chances to constrain these long run frequencies. The following quote comes from a description of Mellor's theory in Berkovitz paper *On Chance in Causal Loops.*

flipped and the relevant circumstances are maintained. Similarly, $F_{S*}(B*/-A*)=Ch_{S,-A}(B)$ would dictate the same equivalency would hold when A-type events do not occur.

Mellor also assumes this principle would hold in relating unconditional long-run frequencies and closest-world chances. Denoting $F_{S*}(A*)$ and $F_{S*}(B*)$ as the unconditional long-run frequency of A-type events and B-type events in S-type circumstances, Mellor assumes that the unconditional long-run frequency of an event is equal to the probability of an event and uses Bayes' Theorem to figure out the unconditional long-run frequency of an event. From this, Mellor gives us his fourth equation to find the unconditional long-run frequency of an event:

4. $F_{S*}(B*)= F_{S*}(B*/A*) \text{ x } F_{S*}(A*)+F_{S*}(B*/-A*) \text{ x } F_{S*}(-A*)$

Mellor uses this equation to state that the long-run unconditional frequency of B-type events in S-type circumstances is equivalent to the long-run conditional frequency of B-type events in the class of A-type events in S-type circumstances times the long-run unconditional frequency of A-type events in S-type circumstances, plus the long-run conditional frequency of B-type events in the class of not A-type events in S-type circumstances times the long-run unconditional frequency of not A-type events in S-type circumstances. Mellor concludes by applying the conditional frequency principle from his first two equations to this third equation to result in what he calls the "*Frequency Principle,*" which dictates that the chances of an event with and without their causes will constrain the long-run unconditional frequencies of these events. The frequency principle is stated in his fifth equation:

5. $F_{S*}(B*)=Ch_{S,A}(B) \text{ x } F_{S*}(A*)+Ch_{S,-A}(B) \text{ x } F_{S*}(-A*)$

This dictates that the long-run unconditional frequency of B-type events in S-type circumstances is equivalent to the chance of event B in its closest S and A worlds, times the long-run unconditional frequency of A-type events in S-type circumstances, plus the chance of event B in its closest S and not A worlds, plus the long-run unconditional frequency of not A-type events in S-type circumstances.

1.6 Mellor's Argument

Mellor's argument for the impossibility of causal loops can be broken down into two distinct steps. The first step Mellor takes is to show that a two-sided loop can be derived from any loop with more than two sides, and if a two-sided loop is not possible, then the loop from which it was derived is also not possible. The second step of his argument shows that two-sided loops result in contradictory frequencies, which makes them impossible, concluding that loops with any number of sides are also impossible (Berkovitz, 2001, p.9).

Let's begin with how Mellor derives a two-sided loop from a multi-sided loop. If we were to have the following three-sided loop in which event A causes event B, event B causes event C, and event C causes event A (figure 2), Mellor believes that from this, we can derive a two-sided loop in which event A causes event B and event B causes event A (Figure 3).

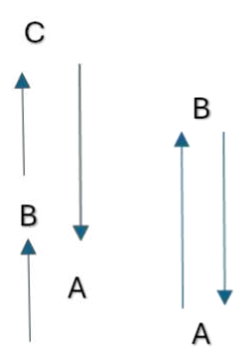

Figure 2. Figure 3.

It's stated that if causal transitivity holds, then the derivation just performed could be assumed. However, Mellor alternatively uses a principle he refers to as *"The Logical Independence of Causal Facts"* in place of causal transitivity. This principle dictates that the chances of event A are logically independent of the causes of event C and the effects of event B. Mellor, in applying this concept, argues that event A causing event B is logically independent of event B causing event A. This would mean that even if event B failed to cause event A due to a failure in causal transitivity, event A could still occur. Therefore, Mellor argues a three-sided loop can only be possible if the two-sided loop derived from it is also possible (Berkovitz, 2001, p.10).

The next step in Mellor's argument is to prove the impossibility of two-sided loops of the kind found in figure 3. To begin, Mellor argues that any combination of individually possible chances must be possible in causal loops because of the *logical independence of causal facts*—the chances of event A and event B are properties of circumstances S and therefore logically independent of each other. Mellor then considers the following chances for events A and B in circumstance S: The chance of event B with event A is 3/5 and without A is 1/5, and the chances of event A with event B is ½ and without event B is 1/5 which we write as follows:

$$Ch_{S,A}(B)=3/5$$
$$Ch_{S,-A}(B)=1/5$$
$$Ch_{S,B}(A)=1/2$$
$$Ch_{S,-B}(A)=1/4$$

From here, we can use the frequency principle to calculate the long-run frequency of event A and event B denoted as $F_{S*}(A*)$& $F_{S*}(B*)$. Plugging these chances into the frequency principle, we get the following equation for the long run frequency of event A:

1. $F_{S*}(A*)= ½ \times F_{S*}(B*)+¼ \times F_{S*}(-B*)$

To find the long-run frequency of event B, we can similarly plug our chances into the frequency principle to get the following equation:

2. $F_{S^*}(B^*) = 3/5 \times F_{S^*}(A^*) + 1/5 \times F_{S^*}(-A^*)$

From here, Mellor argues that the relations between frequencies and chance cannot hold when applied to this loop. If we were to say that the long run frequency of event A* in S* were ½, $F_{S^*}(A^*) = ½$, then by plugging it into the frequency principle for the long run frequency of event A*, we get the following equation:

3. $½ = ½ \times F_{S^*}(B^*) + ¼ \times F_{S^*}(-B^*)$

From here, we can use equation 2 to calculate $F_{S^*}(B^*)$ and $F_{S^*}(-B^*)$ by plugging in ½ for $F_{S^*}(A^*)$ and $F_{S^*}(-A^*)$:

4. $F_{S^*}(B^*) = 3/5 \times ½ + 1/5 \times ½$

This gives us $F_{S^*}(B^*) = 2/5$ and $F_{S^*}(B^*) = 3/5$, which we then plug into Equation 3:

5. $½ = ½ \times 2/5 + ¼ \times 3/5$

This reduces to

6. $½ = 7/20$

This, of course, is a contradiction. Mellor argues that this contradiction proves that loops of this kind are impossible, because the chance that an effect has with its cause fails to constrain the corresponding long-run frequencies according to the frequency and conditional frequency principles.

1.7 Berkovitz's Response

In his paper *On Chance in Causal Loops*, Joseph Berkovitz replies to Mellor's argument for the impossibility of causal loops. Berkovitz argues that the failure of the frequency principle is due to the long-run frequencies being in biased reference classes in causal loops. The frequency principle, as laid out by Mellor, dictates that chances constrain the long-run frequencies of events of the same type, but Berkovitz argues that the failure of this principle, resulting in an inequality between an event's chance and long-run frequency, is unproblematic, because it applies only to frequencies calculated with what he calls unbiased reference classes, and, he argues, reference classes in causal loops are always biased.

But what does it mean for a reference class to be biased, and why do biased reference classes result in different long-run frequencies? An events Reference class is defined by the circumstances and conditions attached to the event in question. For example, if we are calculating the long run frequency of X* events given Y* events in S* circumstances. Then the reference class for X* events is all S* circumstances in which a Y* event occurs. (Berkovitz, 2001, p.10).

For clarification, we need to draw a distinction between bias and determinate bias—while a biased reference class may favor one outcome over another, a determinately biased reference class can only ever produce one outcome. In most cases of causal loops, there will be a determinately biased reference class. We discuss cases of biased reference classes in causal loops in a later section of this paper; for now, when we speak of biased reference classes, we mean only determinately biased reference classes

Now consider the following example of a causal loop in which event A is an indeterministic[9] cause of event B, event B is a deterministic cause of event C, and event C is a deterministic cause of event A (Figure 4).

Figure 4.

If we say the chances of event B with and without event A in circumstance S are 2/3 and 0 respectively, $Ch_{S,A}(B)=2/3$ and $Ch_{S,\sim A}B)=0$ then the conditional frequency principle says the long-run frequency of B* events in the reference class of A* events is 2/3, $F_{S*}(B*/A*)=2/3$. We however know that the conditional frequency principle fails due to B* events being in a biased reference class. While Mellor argues for the impossibility of causal loops due to this failure of the conditional frequency principle, Berkovitz thinks this failure should be expected in causal loops. Stating that while in a case of linear causation this equivalency would hold, in nonlinear cases such as causal loops the conditional frequency principle fails. This is due to the long-run frequency of B* events being in a biased reference class. Although A* events are an indeterministic cause of B* events, the reference class of A*&C* events in S* circumstances is biased towards A* events that bring about B* events. Since the existence of C* events would

[9] The dotted lines of the arrow represent event A being an indeterministic cause of event B.

indicate A* events that only bring about B* events. We see this by calculating the long-run frequency of B* events in the reference class of A* and C* events (Berkovitz, 2001, p.17).

To see this we can start by first calculating F_{s*}(B*/A*) which asks in all the cases in which A* events occur, how many of those cases also have B* events occur? We know since A is an indeterministic cause of event B with a 2/3 chance. This would mean that in 2/3 of cases in which A* events occur, B* events also occurs. From here, we can calculate F_{s*}(A*/C*). Since we know event C is a deterministic cause of event A. It would follow that in all the cases in which C* events occur, A* events also must occur. Next, we can look at the long-run frequency of B* events in the reference class of C* events or F_{s*}(B*/C*). Since event B deterministically causes event C, we can say that in all cases in which C* events occurs, B* events also occur, so F_{s*}(A*/C*)=1 and F_{s*}(B*/C*)=1. We can now calculate F_{s*}(B*/A*&C*), which asks, given all the cases in which both A* and C* events occur, how many of these cases also have B* events occur? It should follow that in all cases in which events A and C both occur, event B also occurs. This is because F_{s*}(A*/C*)=1 and F_{s*} (B*/C*)=1 or in all cases in which C* events occur, both A* and B* events also occur, and therefore, in all cases in which both A* and C* events occur, B* events must also occur giving us F_{S*}(B*/A*&C*)=1. This would also mean that the long run frequency of B* events in the reference class of A* events is biased by C* events due to only including A* events which brings about B* events. Which would mean F_{s*}(B*/A*) =1 as opposed to its original ascription of 2/3 resulting in the failure of the conditional frequency principle.

While Berkovitz's argument was intended to refute Mellor's argument by showing that the failure of the frequency principle was due to these biased reference classes, we can draw the following claims from his argument. Firstly, the long-run frequency of events in a causal loop is determinately 1 except for cases of preemption and overdetermination[10]. Second, if an event in a causal loop is ascribed an indeterminate chance, there will be an inequality between the chance and long-run frequency, which will dictate the failure of the frequency principle.

[10] preemption occurs when an event X pre-empts another event Y from causing event Z. Which would mean that if event X fails to occur event Y could still cause event Z. While overdetermination occurs when event X and event Y both cause event Z. Which would also mean that if event X fails to occur event Y could still cause event Z to occur.

CHAPTER 2

2.1 Bilking and Autoinfanticide

In this section, I will argue that the bilking argument against backward causation fails due to foiling events occurring at determinate frequencies. Commonly postulated as the autoinfanticide objection to time travel which we can examine in detail using Lewis's example:

> "Consider Tim. He detests his grandfather, whose success in the munitions trade built the family fortune that paid for Tim's time machine. Tim would like nothing so much as to kill Grandfather, but alas he is too late. Grandfather died in his bed in 1957, while Tim was a young boy. But when Tim has built his time machine and traveled to 1920, suddenly he realizes that he is not too late after all. He buys a rifle; he spends long hours in target practice; he shadows Grandfather to learn the route of his daily walk to the munitions works; he rents a room along the route; and there he lurks, one winter day in 1921, rifle loaded, hate in his heart, as Grandfather walks closer, closer."
> -(Lewis 1975)

The bilking argument argues that if an effect occurs before its cause, one could attempt to bilk or prevent the posterior cause after the effect has already occurred. Successful bilking attempts, such as killing one's grandfather in the past, result in two contradictions. Firstly, a bilk would involve changing the past so that two contradictory events/facts are true. For example, it is a contradiction to suppose that in 1921, Tim's grandfather was both alive and dead. The next contradiction follows from the results of this change to the past. The bilking event in changing the past produces a sequence of events that will eventually contradict/prevent the bilking from occurring. For example, killing his own grandfather in 1921 subsequently results in Tim not being born, and this consequently results in him never killing his grandfather. The bilking and autoinfanticide arguments follow if backward causation/backward time travel is possible then such bilking attempts could be carried out resulting in impossible contradictions. Therefore, backward causation/backward time travel must be impossible.

David Lewis (1976) offers one of the most compelling responses to autoinfanticide and bilking arguments. He argues that bilking attempts are always foiled by the occurrence of common everyday events that prevent them from succeeding. For example, Tim's assassination attempt on his grandfather may be foiled by him slipping on a banana peel or his gun jamming. These events, which we will refer to as foiling events, are strongly correlated to bilking attempts, often resulting in their ascription as uncaused coincidences. Though we will explore this notion of coincidence more extensively when we examine Horwich's argument, our current focus will be on explaining why these foiling events occur. In the next section, I will argue that these bilking attempts can be coherently understood within the context of causal loops

2.2 Bilking Loops

In this section, I argue that temporal paradoxes which solutions are sometimes modeled as Mobius loops should instead be modeled as causal loops with indeterminate chances[11]. These temporal paradoxes involve backward time travel that consists of a bilking attempt (Tim attempting to kill his grandfather) and a bilking event (Tim killing his grandfather). These are distinct from coincidence solutions, which consist of bilking attempts followed by foiling events that prevent their success. Mobius loop models fall subject to what Smith(1997) calls the "*Second-time-Around Fallacy"*:

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[11] The term Mobius loop comes from Richard Hanley's paper No End In Sight: Causal Loops in Philosophy physics and Fiction which states *"*sometimes included in 'causal loops' are putative arrangements that are straightforward logical impossibilities. An example is the inaptly named 'Möbius' loop which is sometimes offered as a solution to time travel paradoxes" (Hanley 2004 p. 126).

> "There can be no first time around of a set of events, with the time traveler absent, followed by a second time around of the very same events, with the time traveler playing a role: for either there is no second time around; or else the second time around is a genuinely distinct series of events,"
> -(Smith, 1997, p.365).

The past is a set of facts about how the world was at a given time. We tend to think about backward time travel in two ways: one can either affect the past (non-Ludovician) or influence the past (Ludovician). To affect the past is to change the past, changing the facts about the way the world was at that point in time. This is an impossibility that falls for the second time around fallacy: changing the past would imply certain facts about the past to be true and not true at the same time, such as Tim's Grandfather being alive and dead in 1921.

In contrast, to influence the past, one traveling back in time would have to result in the past staying the same. That is, one's backward time travel would produce or be conducive to the facts about the world at that time. For example, if one were to travel back in time to stop JFK's assassination in 1963, then two possible outcomes could result. If they succeeded in preventing the assassination, then they would have effectively affected the past. If they failed to stop the assassination or somehow accidentally caused it by trying to prevent it, they would have influenced the past.

Modeling the grandfather paradox as a Mobius loop means presenting what is a logical impossibility as something coherent[12]. We can classify the paradox as a Mobius loop with the following events:

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[12]Some non-ludovician theorists argue against the impossibility of these paradoxes given alternative timelines or multiverse theories. For more information of these theories Effingham section on non-ludovician probability (Effingham 2021)

Event A: Tim's Grandfather was alive in 1921.

Event B: Tim is born. Tim's Grandfather dies in 1956.

Event C: Tim travels back in time to kill his Grandfather.

Event D: Tim attempts to kill his Grandfather in 1921.

This leads us to a new contradictory set of events:

Event ~A: Tim successfully killed his Grandfather in 1921.

Event ~B: Tim is not born, and Tim's grandfather doesn't die in 1956 (he died in 1921)

Event ~C: Tim doesn't travel back in time to kill his grandfather.

Event ~D: Tim doesn't attempts to kill his Grandfather.

This leads us back to the beginning of our original set of events, beginning with event A: Tim's grandfather is alive in 1921 (Figure 5).

Mobius Loop

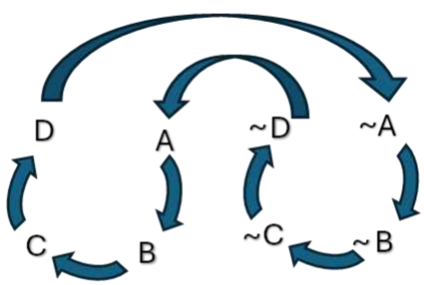

Figure 5.

This situation falls subject to the second-time-around fallacy as it takes the sequence of events to occur more than once. There is a first time around where the first set of events (A, B, C, D) occur. This is then followed by a second time in which a new sequence of events (-A,-B,-C,-D) occurs.

In addition to the second-time-around fallacy, Mobius loops are also mistaken in supposing that the past can change. The second sequence of events, being different from the first sequence, implies the possibility of a contradiction we know to be impossible under a Ludovician view. Furthermore, Mobius loops model the occurrence of bilking events, which we know to be metaphysically impossible. So, how should we model autoinfanticide cases like the grandfather paradox and other similar temporal paradoxes? The answer is quite simple: they cannot be coherently modeled. Instead, we should model the coincidence solutions as the true sequence of events—rather than modeling the bilking attempt and the bilking event followed by a second sequence of events, we should instead model the bilking attempt followed by the foiling event. For example, Tim slipping on a banana peel and missing his shot (the foiling event), which we can call event E, would be the event that takes place due to the metaphysical necessity of such a foiling events.

In this new causal chain, event ~A (Tim killing his Grandfather) is now only a counterfactual to event E. While event ~A is metaphysically impossible, it still has a positive chance of occurring. Tim's attempt to kill his Grandfather (event D) will either result in the occurrence of the bilking event(~A) or the foiling event (event E). This new causal chain of events is now a negative causal loop rather than a Mobius loop (figure 6). That is, Tim slipping on the banana peel (event E) results in his Grandfather being alive in 1920 (event A), which causes Tim to be born (event B). Tim's Grandfather dies in 1956 (event C), which in turn causes Tim to travel back in time to kill his Grandfather (event D), which results in Tim either killing his grandfather(~A) or slipping on the banana peel (event E).

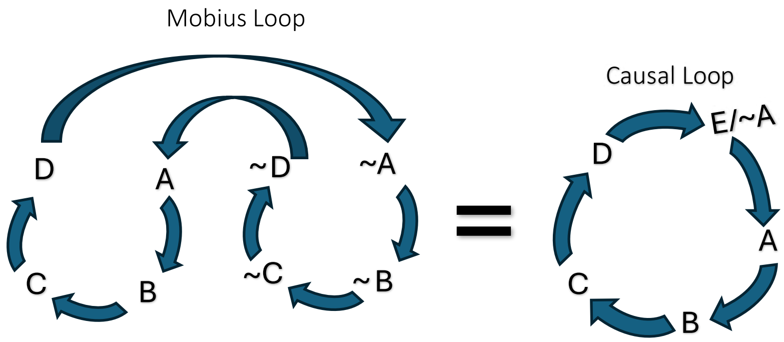

Figure 6.

The idea of autoinfanticide attempts and similar bilking attempts that result in temporal paradoxes being modeled as negative causal loops comes from Nick Effingham's book *"Time Travel Probability and Impossibility"*.

> "Start by considering a negative causal loop. Imagine I go back to kill Pappy. I fail to do so and have a heart attack as soon as I step out in the past. Imagine that the laws of physics are substantially different from our own, and that my appearing in the past doesn't have any (positive) causal impact on Pappy (e.g., the gravity caused by my mass doesn't affect Pappy's molecular structure etc.). So no positive causation affects my personal history, although the negative event of my failing to kill Pappy is a (partial) cause of Pappy living, going on to father my father, and then in turn my father fathering me. In turn, that's a (partial) cause of my using the time machine to step out into the past, where I have my heart attack. Thus, a negative event ends up being a partial cause of itself. Call cases where negative events cause themselves 'a negative causal loop"
> -(Effingham, 2019, p.149).

Using the same method reversed in causal loops, we can see which counterfactuals with positive chances would produce Mobius loops if they were to occur i.e. events that create self-defeating causal chains. Consider, for example, our coin flip situation with one key change: the coin only enters the wormhole if it lands heads:

Event A: At noon, Joe finds a magic coin heads up on his kitchen table.

Event B: Joe flips the coin.

Event C: The coin lands heads-up and travels through the wormhole, appearing on Joe's

kitchen table at 11:45 a.m.

Event ~C: The coin lands tails-up and no time travel takes place (Figure 7).

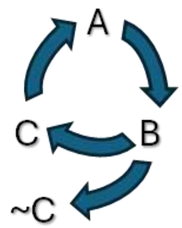

Figure 7.

If the coin lands tails, the change here results in a possible Mobius loop. If this is a fair coin toss, then the chance that B causes C is equal to the chance that it causes ~C. ~C is the bilking event, since the coin not traveling back in time results in it never being found and consequently never being flipped. We can see here that even though ~C can have a non-zero chance, its occurrence is metaphysically impossible. This is due to ~C being a bilking event, an event that not only changes the past but, in doing so, produces a chain of events that would result in a self-defeating Mobius loop if it were to occur.

The modeling of autoinfanticide attempts and other temporal paradoxes as events in a causal loop hasn't seen much discussion within the literature on nonlinear causation and time travel. Clarifying this will be the first step in my argument; since Mobius loops are impossible, we should not examine autoinfanticide attempts and other temporal paradoxes as such. Rather, we should understand them as a product of ascribing indeterminate chances to events in causal loops. Bilking events like killing one's grandfather or the coin landing tails shouldn't be thought of as producing their own causal chain and resulting Mobius loops. Instead, we should consider these events as alternative possibilities or counterfactuals to foiling events in causal loops. Their positive chance of occurring is only a product of ascribing indeterminate chances to metaphysically necessitated foiling events (such as slipping on banana peels or the coin landing heads).

In addition to establishing that we should model temporal paradoxes as causal loops, the above arguments also motivate the following first premise:

> 1. Situations involving backward time travel and a bilking attempt should be modeled as causal loops, with bilking attempts being followed by foiling events that prevent the occurrence of a bilking event.

2.3 Coincidence and The Frequency Principle

We now turn to the sense in which foiling events are coincidental. The traditionalist view holds coincidences to involve an association between two or more events that are causally independent of one another (Lando 2016), but authors such as Lando (2016) and Bhogal (2019) have brought difficulties facing the traditionalist view of coincidence to attention. Advocating for a new conception of coincidence that strays from the notion of causal independence, Lando, in his paper C*oincidence and Common Cause,* argues that the traditional account is mistaken because a common cause can be found in some cases of coincidence. He provides the following example of an intuitive coincidence to point out this issue.

> "A boy is playing with a ball in the courtyard of an apartment complex. He throws the ball too high, and it bounces off of the balcony of one apartment, sails through the air, bounces onto the balcony of another apartment, and finally falls to the ground. On each of the two balconies sits a grand piano. As the ball lands on the first balcony it strikes a note on the first piano, and as the ball lands on the second balcony, it strikes a note on the second piano. On each of the two pianos, the note struck is the high A."
> -(Lando, 2016, p. 135)

In this example, the separate events of the ball hitting the high A note are cited as an intuitive coincidence, yet a common cause can be found in each event being caused by the boy throwing the ball. This goes against the traditionalist view's notion of associated events being causally independent of one another.

We can arguably see the same phenomenon in our formulation of bilking attempts as causal loops. Posed as a causal loop, the associated events of attempting to kill my younger self (bilking attempt) and my slipping on a banana peel (foiling event) are no longer causally isolated. Since each event within a causal loop is a cause of all the prior and subsequent events, this would mean no events within a causal loop can be causally independent of one another.

This argument is not, however, uncontroversial. As we have already seen, Mellor, for example, has argued that causal independence in causal loops holds. He refers to this notion as *The Logical Independence of Causal Facts*—"facts about whether or not B fails to cause A are logically independent of the fact that A causes B. So even if B actually fails to cause A (due to a failure of causal transitivity), it is logically consistent to assume that it does" (Berkovitz, 2001, p.10). Additionally, according to authors such as Lando and Horwich, foiling events are causally inexplicable, stating "it is a truism that coincidences cannot be explained. Assuming that the sort of explanation at stake here is causal explanation, the truism informs us that coin-cidences do not admit of causal explanation" (Lando, 2016, p. 132).

I argue, however, that such events are at least a partial cause, following authors such as Effingham (2020). Bilking attempts are a cause of foiling events because bilking attempts must occur for foiling events to occur. Akin to how entering a dance competition is a necessary condition of you losing a dance competition. Attempting to kill one's younger self is a necessary condition of you failing to kill your younger self. It is counterfactually true that if Tim did not attempt to kill his grandfather, then he wouldn't have slipped on the banana peel. If this is the case, then the traditional view fails to capture what we view as coincidence; instead, we should look for a new way to define the coincidences we are examining in these nonlinear cases.

I, however, seek to sidestep this debate by focusing instead on a different intuitive aspect of coincidences: that coincidences are improbable/unlikely. Authors such as Hart and Honore maintain that “a coincidence must be very unlikely by ordinary standards and for some reason significant or important.” (Hart, Honore, 1959, p.74). It seems to follow that our intuitive notion of coincidence requires that the associated events are unlikely, and this will be the focus of our use of coincidence in the rest of this paper. So, while I allow that coincidences may remain causally inexplicable, I argue that the improbability associated with coincidence can be explained.

Imagine, for example, that when randomly pulling cards out of a deck, one were to draw all 13 hearts in a row; or when flipping a coin, one were to get ten heads in a row. These cases are both coincidental, and the coincidence follows from the unlikelihood of such associated events obtaining, rather than the inexplicability of the events themselves. Similarly, in Horwich's example (Horwich, 1995, p.263), in which banana peel slips or gun jams foil multiple autoinfanticide attempts, these foiling events are unlikely to occur with such frequency.

My argument holds that the frequency with which these improbable events occur can be attributed to the failure of the frequency principle. When we pull 13 hearts out of a deck of cards or land a coin heads 10 times in a row, we see what has occurred as improbable due to the chance of the event failing to constrain the frequency with which the event occurs. If a fair coin flip’s chance of landing heads is .5, its frequency would be equal to or close to .5. The frequency of heads being 1 rather than .5 over ten flips can be seen as an improbable coincidence.

Here, we can note an important distinction between the two uses of coincidence in discussing these bilking attempts. The first from authors such as Lewis (1976), holds singular cases of foiling events as coincidences. In these cases, particular bilking attempts such as attempting to shoot yourself in the past will always entail coincidental foiling events such as slips on banana peels, which are inexplicable in their occurrence. The second use of coincidence can be derived from Horwich (1995) and will be the view we use when referring to coincidence. Under this view, coincidences are more akin to a rule or a law. For example, it follows that every bilking attempt fails to produce a bilking event due to the occurrence of a foiling event, and it is a coincidence that this is always the case.

We can see here that the improbability of this type of coincidence is not due to the improbability of any singular outcome but multiple associated outcomes over multiple trials. A singular coin flip landing heads wouldn't be considered a coincidence, nor would a second toss with the same result. It is only after multiple trials that we begin to see the improbability we associate with coincidence, and this is obtained only after there is enough evidence to suspect a disconnect between the chance and frequency at which we observe the occurrence. So, in our autoinfanticide case, it is not a coincidence that our attempt failed due to a banana slip or gun jam. The coincidence is that all autoinfanticide attempts always fail due to banana slips or gun jams.

To make this more concrete, consider an example based on Horwich's thought experiment: In the future, one hundred people are sent back in time to kill their younger selves, and each of these attempts is stopped by things like banana slips and gun jams (foiling events). Suppose that each of these foiling events had a .01 chance of occurring. It would be a highly improbable coincidence if all one hundred autoinfanticide attempts failed due to the occurrence of foiling events always taking place. However, as we know, this is what would happen. We can see in this example that foiling events have only a .01 chance of occurring, yet foiling events always occur, which means their frequency of occurring is 1. The chances that these foiling events have of occurring are disproportionate to the frequency at which these events occur, resulting in these events being coincidences. This giving us our second and third premise:

2. It is a coincidence that bilking attempts always entail foiling events.

3. This coincidence can be explained by the failure of the frequency principle in causal loops.

Now that we have seen how the improbability of coincidences can be understood as a failure of the frequency principle, the next section examines the reason the frequency principle fails in causal loops.

2.4 Coincidence in Loops

The picture we have drawn establishes that temporal paradoxes can be coherently modeled as causal loops. These causal loops include a bilking attempt followed by a foiling event rather than a bilking event. Both foiling events and bilking events have positive chances, yet these foiling events are bound to occur while the bilking event's occurrence is metaphysically impossible. It is an improbable coincidence that bilking attempts always entail the occurrence of foiling events, and this improbability can be understood as a failure of the frequency principle. This principle fails because foiling events' chances fail to constrain their long-run frequency. In this section, I argue that we should not expect the frequency principle to hold in these circumstances, due to the long-run frequencies always being calculated with respect to biased reference classes, and that therefore the improbability of the foiling events always occurring does not give us reason to believe that time travel itself is also improbable.

Returning to our coin example from above, in which Joe walks into his kitchen at noon to find the magical coin heads up on his kitchen table:

Event A: At noon, Joe finds a magic coin heads up on his kitchen table.

Event B: Joe flips the coin.

Event C: The coin lands heads-up and travels through the wormhole, appearing on Joe's kitchen table at 11:45 a.m.

Event ~C: The coin lands tails-up and no time travel takes place.

~C is the bilking event, because its occurrence would be a change to the past that results in a self-defeating causal chain. This means that B can be seen as our bilking attempt. It will either cause the bilking event (~C) or the foiling event (C). Since this is a fair coin flip, we can say C and ~C both have a .5 chance of occurring:

$$Ch_{S,B}(C)=.5$$
$$Ch_{S,B}(\sim C)=.5$$

According to the conditional frequency principle, then, we would expect the long-run frequencies of C* and ~C* to both be .5 as well:

$$F_{S^*}(C^*/B^*)=.5$$

$$F_{S*}(\sim C^*/B^*)=.5$$

We additionally know that the chances of C and ~C without B are 0:

$$Ch_{S,\sim B}(C)=0$$
$$Ch_{S,\sim B}(\sim C)=0$$

While we know that due to being in a biased reference class the frequency of C* without B* will be 0 and with B* determinately 1. We can see why this is by looking at the long run frequency of event C* in the reference class of events B* and event A* or $F_{S*}(C^*/B^*\&A^*)$. To find this, we first must find the long-run frequency of event B* given event A*, $F_{S*}(B^*/A^*)$. This requires us to answer the following questions: Given all cases in which A* events occur, how many also have B* events occur; in our case, given all cases in which Joe finds the magic coin, how many also have Joe flipping the magic coin? The answer to this question is all of them, since the coin being flipped and traveling back is a necessary requirement for it to be found, giving us $F_{S*}(B^*/A^*)=1$. Next, we can look at $F_{S*}(B^*/C^*)$ or the long-run frequency of event B*, given the occurrence of event C*. We can calculate this frequency by asking, given all cases in which C* events occurs, how many also have B* events occur; again, in our example, given all cases in which the coin lands heads and travels back in time, how many have Joe flipping the magic coin? Once again, the answer is all of them, since the coin landing heads is a necessary requirement for it traveling back in time to be found, giving us $F_{S*}(B^*/C^*)=1$.

We can now return to calculating $F_{S*}(C^*/B^*\&A^*)$ by asking, given all cases in which B* and A* events occur, how many have a C* event occurring; in our case, given all cases in which Joe both finds the magic coin and flips the magic coin, how many also have the coin traveling back in time and landing heads? Given $F_{S*}(B^*/A^*)=1$ and $F_{S*}(B^*/C^*)=1$, we know that in all cases in which a B* event occurs, an A* event and C* event also occur, and so we know

$F_{s*}(C*/B*\&A*)=1$, and subsequently $F_{s*}(C*/B*)=1$, as opposed to the .5 predicted by the conditional frequency principle. From this we can see that even though B* is an indeterminate cause of C*. Giving both C* and ~C* an equal chance of occurring, the frequency of C* events in the biased reference class of B* and A* events is determinately 1. This would also mean the long-run frequency of event ~C* is 0 as opposed to its initial predicted of .5. These long-run frequencies correspond well with the notion that bilking events such as event ~C* (landing tails) are metaphysically impossible and foiling events such as event C* (landing heads) are metaphysically necessitated, even though both have an equal .5 chance of occurring.

Posing all bilking attempts as causal loops and using this method incur similar results of determinate frequency due to biased reference classes. As stated before, the coincidence is not the occurrence of any singular foiling event in the face of bilking attempts, but rather that all bilking attempts are met with foiling events. The reason this coincidence obtains is that foiling events have determinate frequencies due to biased reference classes. Berkovitz's argument and framework allow us to see why the chances of events are disproportionate to their long-run frequencies, and our application of this argument to bilking attempts modeled as causal loops explains the improbability of the coincidence that all bilking attempts appear alongside foiling events.

2.5 Bilking Events vs CPC Events

I have shown why it is the case that bilking attempts result in foiling events with determinately long-run frequencies due to being in a determinately biased reference class. I now argue that this is not always the case. If an event's occurrence would change the past but not produce a self-defeating causal chain (SDC), then the event would not be a bilking event;

we instead call it a change to the past contradiction or CPC event. We can go back to the coin example to explain this distinction further, but with the change that the coin travels back in time no matter the result of the flip. In the previous version of the example, the coin could only travel back if it landed heads up. Landing tails would bilk the sequence of events, producing a SDC since landing tails would mean no time travel takes place, resulting in the coin never being found or flipped. In this new example, however, if we were to say the coin was found heads up, then the coin landing tails would be a CPC, and this change would not produce an SDC. Even if the coin lands tails, it will still be found and flipped, and the causal loop will still obtain[13].

As noted in the earlier discussion of Berkovitz's response, a biased reference class may favor one outcome over another, while a determinately biased reference class will only produce one outcome. This distinction is important due to the tendency for bilking attempts to result in events with determinately biased reference classes while CPC attempts only produce events with biased reference classes. This also means that SDC attempts such as bilking attempts would result in foiling events that are in a determinately biased reference class which will only ever produce a long-run frequency of 1 or 0. While CPC events that would only change the past would result in foiling events in a biased reference class which would only produce long-run frequencies that favors the occurrence of the foiling event.

In this section, I will show why events counterfactual to CPC events are in non-determinately biased reference classes and, therefore, can have indeterminate long-run frequencies. Berkovitz states in his paper that events in causal loops are always in

[13] It is an open question whether such a change to the past is logically possible (that is for the Ludovician and non-Ludovician to argue about).

(determinately) biased reference classes except in cases of preemption and overdetermination (Berkovitz, 2001, p.19). Preemption and over-determination occur when an event's occurrence is not determinately caused by another event in the causal loop. Consider for example, a causal loop in which event A causes event B, event B causes event C, event C causes event A, and event D causes event C. Preemption means that a separate cause for some event is being prevented or superseded; this would be an example of preemption if B causes C and D does not, but if B were to not occur, D would cause C (Figure 8).

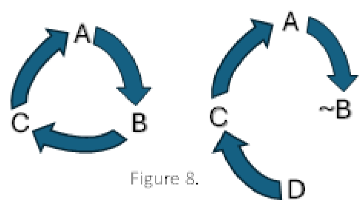

Figure 8.

Overdetermination, in contrast, means that multiple events cause some event; this example would instead involve overdetermination if D and B both cause C, so that, even if B were to not occur, D would still be sufficient to cause event C (Figure 9).

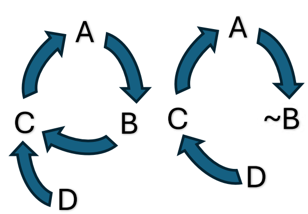

Figure 9.

To explain these cases of preemption and overdetermination and their relation to CPC events, we can look at Hanley's example in his paper *No End in Sight.* In this example, a time traveler visits a pregnant couple discussing the name of their unborn child. The time traveler suggests the name Ben to the couple having already known that the couple would name their unborn child Ben. The couple, having not previously considered the name, decided to name their child Ben. The causal loop in this case involves information—specifically the name Ben. The name seems to have appeared ex nihilo—neither the time traveler nor the couple seem to have originated the name (Hanley, 2004, p.134).

We can represent this example with the following set of events:

> Event A: the time traveler visits a couple about to have a baby.
>
> Event B: The time traveler suggests the name Ben.
>
> Event C: The couple name their baby Ben.
>
> Event D: The time traveler meets Ben before traveling to the past to visit the couple.

In Hanley's example, the time traveler does meet Ben in the future but is unaware of Ben and the child being the same person; therefore, the time traveler only suggests the name Ben due to recently hearing the name (when meeting future Ben). Hanley claims the coincidence to be the time traveler randomly suggesting the name Ben for the child, which turned out to be the child's name. The time traveler could have suggested any name, but it is a coincidence that they happened to pick the name the child would be called.

This example, however, can be modeled with a CPC and subsequent overdetermined event, if the couple intended to name their child Ben before the name was suggested or if an additional event still causes them to name their child Ben. Then ~B (the time traveler suggests any other name) would only be a CPC event rather than a bilking event as long as C (The couple names their baby Ben) occurs, either because another cause of C was preempted or because C was overdetermined. In this example, if ~B takes place, C, D, and A would all still occur, so ~B would not be a bilking event. If suggesting the name Ben is not a determinate cause of subsequent events, including itself, then its counterpart (~B) is only a CPC rather than a bilking event.

This means that events such as B are only in biased reference classes rather than determinately biased reference classes which dictates that the long-run frequency would be greater than its chance but is not determinately 1. To find out the biased long-run frequency of B in a causal loop where there is an overdetermined cause P (such as Jim suggesting the name Ben) of event C, we would have to find $F_{s*}(B*/C*)$. If either B or P could cause C, and if we were to say B has a .5 chance, and P has a .3 chance, then C would have a .65 chance of occurring. This would also give us a .15 chance for P to cause C when B does not occur and, a .35 chance for B to cause C when P does not occur, and a .15 chance for C to be caused by both B and P. By adding the times in which B causes C, with all the times in which B and P cause C we get all the cases in which both B and C occur giving us $F_{s*}(B*/C*)=.5$ which would align with its chances. If this were a determinately biased reference class, B would also occur in all cases in which C occurs, resulting in $F_{s*}(B*/C*) =1$. Instead, only in .65 percent of cases does C occur, meaning that to calculate the long-run frequency of B* in the reference class of C*, we would have to divide our .5 frequency of B* by the .65 frequency of C* giving us $F_{s*}(B*/C*) =.769$. Though the frequency of B* isn't 1, meaning it’s not in a determinately biased reference class. The frequency of B* is still in a biased reference class since B’s frequency diverges from its original chance ascription of .5. This would dictate a frequency that is biased towards the occurrence of B even though B and ~B both have an equal .5 chance of occurring. We can see here that in causal loops, even though bilking attempts entail foiling events with determinately biased reference classes, CPC attempts entail the possibility of both CPC events and ~CPC events if an overdetermined or preempted subsequent event follows them.

CHAPTER 3

3.1 Horwich's Backward Causation Argument

Horwich's argument begins not with his argument against backward time travel but with his argument against backward causation. While neither concept necessarily implies the other, many cases of backward time travel imply the occurrence of backward causation. Backward causation involves a cause that occurs after its effect has taken place. Horwich notes that a common objection, the bilking argument, presents a serious issue for the backward causation hypothesis. This objection holds that if an effect occurs before its cause, one could attempt to bilk or prevent the posterior cause after the effect has already happened. Take the following case of backward causation: Houdini always predicts a coin flip's result. Houdini's predictions, however, do not cause the coin flip's result. Instead, it is the flip's result that causes Houdini's predictions, making this a case of backward causation (Faye, 2024). If Houdini made his prediction, but the coin flip was prevented, we would have successfully bilked the cause of the prediction after the prediction had already taken place.

> "Repeatedly wait to observe the presence (or absence) of the alleged effect E and then try to prevent (or produce) the subsequent alleged cause L. If this policy is carried out, then E will often occur in the absence of L, and L will frequently fail to bring about E. So, the backward causation hypothesis is false. If, on the other hand, the attempt to carry out the policy fails, this indicates that an agent's ability to produce L depends on the prior presence of E, which in turn means that E is a necessary causal antecedent of L. Thus, whatever happens, the hypothesis will be falsified."
> -(Horwich, 1987, p.92).

The bilking argument shows how, no matter the outcome, bilking attempts present issues for the backward causation hypothesis. If the cause fails to occur after the effect takes place, then this would show a lack of causation. If instead the cause cannot be prevented after the effect takes place, then this would show the effect to be a necessary cause, making this a normal case of causation rather than a case of backward causation. For example, if Houdini makes a prediction and the coin flip never takes place then this would show the two events to be causally independent. if instead the coin flip's occurrence is necessitated when the prediction occurs, then this would show the prediction to be the cause of the flip rather than the other way around.

Horwich argues that the bilking argument does not show the backward causation hypothesis to be false; rather, "what the bilking argument shows is that backward causation would engender inexplicable coincidences" (Horwich, 1982, p.93). Horwich argues that in cases of successful bilking attempts the failure of the cause to occur does not falsify the backward causation hypothesis. He argues that the cause may or may not produce the effect, and therefore, its failure to occur after an effect has taken place cannot eliminate the notion that this may be a case of backward causation. He argues that the failure of the cause to occur when the bilking policy is implemented only shows a correlation between the two events. Horwich concludes that this case can only show us that there is an uncaused correlation between the bilking attempt and the failure of the cause to occur. So, what we are left with is an inexplicable coincidence.

Horwich argues that similar results ensue in bilking cases where the cause doesn't fail to occur. He divides these cases of failed bilking attempts into two camps. The first case addresses the argument that the effect is the necessary condition for the cause, resulting in a normal case of causation. Horwich argues that effects have causal antecedents which determine their occurrence independently of the subsequent cause.

> "if we suppose that, in addition to these causal antecedents, such events have subsequent causes, then we are supposing that these events are regularly causally overdetermined; we are recognizing an association between the earlier determinants of E and the later determinants of E But, according to the unorthodox interpretation, there is no causal connection between these correlated phenomena."-(Horwich, 1982, p.96)

He argues that we are left with another inexplicable coincidence since we again have an uncaused correlation.

The second case examines bilking attempts that fail due to interfering circumstances. For example, in our Houdini prediction case, we could try to bilk the coin flip by stealing the coin before it could be flipped. Our bilk could be prevented by interfering circumstances such as slipping on a banana peel. Horwich argues that, again, we are left with a coincidence due to a correlation between bilking attempts and events that prevent those attempts from succeeding.

Horwich goes on to distinguish between two types of inexplicable coincidences: an improbable Humean type and a Non-Humean type. Both types of coincidences are uncaused correlations due to violating what Horwich refers to as *"The Principle of Causal Correlation".* Horwich argues that this principle can be violated in two ways by violating *"The Principle of V Correlation",* which dictates:

> "that highly correlated events are always constituents of a V-shaped pattern of correlation. Very roughly speaking, if events of type A and B are associated with one another, then either there is always a chain of events between them, or else we find an earlier event of type C that links up with A and B by two such chains of events." (Horwich, 1982, p.97).

Alternatively, Horwich argues that inexplicable coincidences can also occur due to violating the Humean conception of causation which dictates "that a cause is an earlier member of a chain of direct nomological determination." (Horwich, 1982, p.97-98). Horwich argues that these Humean type coincidences are improbable due to violating The Principle of V Correlation. He states that correlated events either have a direct causal connection or a prior event that connects them: "What we do not see is the pattern...in which A and B are connected only with a characteristic subsequent event, but no preceding one" (Horwich, 1982, p.97). His argument claims that these types of correlated events are improbable since we do not observe this pattern of correlation in our world.

Horwich claims that the coincidences that arise in bilking cases can be of the non-Humean or improbable Humean type. However, He argues that this provides no grounds for the impossibility or improbability of backwards causation stating:

> "It seems to me that the bilking argument is indeed redundant. It merely highlights the fact that backward causation involves uncaused correlations and does not reveal it, because this fact could perfectly well have been discerned without reference to bilking considerations."(Horwich, 1982, p.101).

While Horwich's conclusion only finds backwards causation to bring coincidences of either type his next chapter makes a more substantive claim against the possibility of backwards time travel.

3.2 Horwich's Backward Time Travel Argument

Horwich's next chapter examines four objections to the possibility of backward time travel. However, like Horwich, our focus will only be on the last objection; Horwich himself quickly dismisses the first three objections. The last objection, termed the autoinfanticide objection, holds that if time travel were possible, then one could go back in time and kill their younger self or prevent their birth from ever occurring. The issue here is that killing their younger self would create a self-defeating causal chain. We can examine Lewis's version of the autoinfanticide objection to see what this self-defeating causal chain would look like.

Event A: Tim's grandfather is alive in 1921.

Event B: Tim is born sometime between 1921 and 1956.

Event C: Tim's grandfather dies in 1956.

Event D: Tim travels back in time to kill his grandfather.

This now gives us the following sequence of contradictory events.

Event ~A: Tim kills his grandfather in 1921.

Event ~B: Tim is not born.

Event ~C: Tim's grandfather doesn't die in 1956 (since he died in 1921).

Event ~D: Tim doesn't travel back in time to kill his grandfather.

We can see here that such self-defeating causal chains are impossible since they presuppose a sequence of events that contradicts the original sequence of events.

> "No conceptual difficulties are involved in the idea of a causal chain in which someone goes on a journey and kills someone at his destination; or in which someone, who remembers that something has not happened to him, goes on a journey and does that thing to someone else. Problems arise only when we consider these causal chains to be located along closed timelike curves. In this situation it may happen that elements of the chain, which usually would be temporally separated, are now required to coincide with each other; yet their coincidence is impossible. The usual ends of the chains (death of the victim) don't 'fit' with the usual beginnings (good health of the killer)."
> -(Horwich, 1987, p.117)

Horwich responds to the autoinfanticide objection by claiming that while autoinfanticide is impossible, it does not follow that time travel is impossible. He begins his argument by categorizing the autoinfanticide problem and all similar self-defeating type paradoxes as bilking attempts, stating:

> "In particular, there is a clear similarity between the concept of bilking and the idea of a self-defeating causal chain. Consequently, we can expect to gain insight into the autofanticide paradox by drawing on our examination of the bilking argument" (Horwich, 1987, p. 120).

As we saw above, Horwich identifies two types of uncaused correlations, Humean and non-Humean. He claims that bilking in the context of time travel will result in improbable Humean type coincidences. The reason for this, he argues, is that bilking in these cases of time travel involves bringing about events that did not occur. For example, in the auto infanticide case, the bilking attempt would be one's attempt to murder their infant self. Horwich's argument is that bilking attempts are bound to fail since they would bring about self-defeating causal chains.

Akin to Lewis (1976), Horwich attributes this failure of bilking attempts to the occurrence of commonplace phenomena that prevent them from succeeding. For example, when I travel back in time and attempt to kill my grandfather (bilking attempt), this attempt will fail due to my gun jamming or a slip on a banana peel. Horwich argues that if time travel into the past were possible, it would require the failure of any bilking attempts, and according to Horwich, there are two possibilities from his argument: either bilking attempts are not common, or bilking attempts will be prevented from succeeding. He argues, however, that

> "Given our experience of the infrequency with which such coincidences occur, we have good reason to believe that the persistent failure of bilking attempts is highly improbable. That is; it is highly improbable that circumstances will often conspire to ensure that bilking attempts do not succeed. From which, together with the previous statement, we can infer Bilking attempts are not common"
> -(Horwich, 1987, p.122).

Horwich poses a thought experiment that poses multiple autoinfanticide attempts to show why this is the case. The thought experiment follows a future in which hundreds of time travelers are sent back to kill their younger selves. Each of these autoinfanticide attempts fails, however, due to the occurrence of gun jams and banana slips frustrating their intentions.

Horwich states:

> "if there were a regular practice of travel into the past, then there would have to be a correlation between, for example, the time traveller having an intention to bump off the child who lives at his old address and the existence of circumstances that will frustrate this intention. And we know enough about human motivation (specifically, about the factor that might produce this bilking inclination) and the kinds of phenomena that could cause this plan to fail (amnesia, gun-jamming, brilliant sur geons, etc.) to claim that any such correlation would be an improbable coincidence" (Horwich, 1987, p. 125).

Horwich's argument against backward time travel claims that these coincidences are improbable due to their violation of the principle of V correlation. They are a correlation between two events only through a subsequent event. For example, event A, my attempt to kill my grandfather, is correlated to event B, my slipping on a banana peel, only through subsequent event C, my failure to kill my grandfather. Then, the correlation between events A and B would be an improbable coincidence because these events are only correlated through the subsequent event C (Dowe, 2003, p.577). Horwich summarizes his argument against backward time travel into the following formal deduction.

1. "If spacetime permits time travel, then men will travel into their local past.
2. If men will travel into their local past, then there will be bilking attempts.
3. Any such bilking attempts will be thwarted.
4. The regular thwarting of bilking attempts will involve an endless string of improbable coincidences.
5. If spacetime permits time travel, then there would occur certain phenomena that we have empirical reasons to believe will not in fact occur.
6. Spacetime does not permit time travel."
   -(Horwich, 1987, p. 123-124)

3.3 Dowe on Horwich's Argument

Phil Dowe reconstructs Horwich's argument in his paper "The Coincidences of Time Travel." He begins by reformulating *The Principle of V Correlation* as "if there is a correlation between two events of types A, B respectively such that P(A.B)>P(A)P(B)"(Dowe, 2003, p.576). Dowe claims that a correlation holds between two events if the probability of both events occurring is greater than the probability of each event occurring individually. For example, during a game of poker, the probability of being dealt a king or a queen out of a deck of standard playing cards is 1/13. So, the probability of pulling a king followed by a queen would be 4/633, giving us our P(A)P(B). However, let's say the dealer is cheating so that the probability of being dealt both a king and a queen is guaranteed, meaning P(A.B)=1. In accordance with Dowe, since 1>4/633, this would mean there exists a correlation between the event of being dealt a queen and the event of being dealt a king. Dowe then explains that "unless there is a direct causal connection between A and B, there is an event C which "screens off " the correlation, i.e., such that P(A.B|C) = P(A|C)P(B|C)" (Dowe, 2003 p.576). For an event to screen off the correlation, it must be a common cause of both events. The probability of both events occurring relative to a common cause C must be equal to the probability of each event individually occurring relative to C. In our example, C is the common cause of the correlated events, is the dealer cheating. This means that the probability of being dealt both a king and queen, given the dealer is cheating, would be equal to the probability of being dealt a king given the dealer is cheating times the probability of being dealt a queen given the dealer is cheating. Since the dealer is guaranteed to deal us both a king and a queen, this would give us $P(A.B|C) = 1$ as well as $P(A|C)=1$ and $P(B|C)=1$ giving us $P(A.B|C) = P(A|C)P(B|C)$. Lastly, Dowe states that "C occurs before A and B" (Dowe, 2003, p.576), which would dictate that a common cause of a correlation must occur prior to the occurrence of the correlated events.

This last stipulation results in Horwich's conclusion that time travel is improbable. Since the common cause of the correlation in Horwich's coincidences occurs after the occurrence of the correlated events. Using the autoinfanticide objection, we can see that there is a correlation between the bilking attempt and the foiling event. This would mean that the probability of the bilking attempt(B)and the foiling event(F) occurring is greater than the probability of each event occurring individually $P(B.F)>P(B).P(F)$. While we do not know the exact probability of the events in question occurring individually, we do know them to be less than 1. Similarly, we know that their occurrence in conjunction is necessitated, giving us a determinate probability of 1. We, therefore, know that $P(B.F)=1$ and $P(B).P(F)=X<1$, meaning Dowes first stipulation of $P(B.F)>P(B).P(F)$ holds, giving us a correlation between the two events. We also know that this correlation holds due to a subsequent common cause(C) in our autoinfanticide case. This is the fact that the person we are trying to kill is our younger self. This event C is a determinate cause of each correlated event, which would mean $P(B.F|C) = 1$ and $P(B|C)=1$ and $P(F|C)=1$ giving us $P(B.F|C) = P(B|C)P(F|C)$. However, since our common cause occurs after our correlated bilking attempt and foiling event violating the last tenet of The Principle of V Correlation, these coincidences and, consequently, backward time travel is deemed improbable.

3.4 Berkovitz on Horwich 's Argument

Dowe's reformulation allows us to examine Horwich's argument in the context of Berkovitz's argument. Dowe's reformulation frames probabilities as the relative frequencies of event occurring, akin to Berkovitz's and Mellors usage of long run frequencies of event types. We can close this gap between the two denotations by framing Horwich's argument in terms of event types rather than particulars. This would mean that rather than posing Horwich's argument as particular bilking attempts and foiling events producing improbable coincidences, all bilking attempts met by foiling events will result in improbable coincidences[14]. For example, in a causal loop in which A causes B which causes C which in turn causes A. B would be our bilking event, which is correlated with C our foiling event, through a subsequent common cause A. Using our bilking attempt example: Joe walks into his kitchen at noon to find a magical coin heads up on his kitchen table. He picks up the coin and flips it. If the coin will land heads, then as the coin reaches its apex and begins to descend, it enters a wormhole and lands on his kitchen table in the same spot a quarter before noon. If the coin lands tails, then no time travel will take place. This gives us the following Causal loop:

Event A: At noon, Joe finds a magic coin heads up on his kitchen table.

Event B: Joe flips the coin, and the coin travels through the wormhole.

Event C: The coin lands heads up where Joe found it a quarter before noon.

We can add event ~C: The coin lands tails, and no time travel takes place (figure 7). This ~C is the bilking event since its occurrence would result in a self-defeating causal chain. This also

[14] Similar to Horwich's usage of coincidence in his thought experiment in which many time travels try to commit autoinfanticide (Horwich, 1975, p.125)

means that B Joe flipping the coin would be our bilking attempt akin to an autoinfanticide attempt. It will either cause the bilking event (~C) or the foiling event (C). Since this is a fair coin flip, we can say both C and ~C have an equal .5 chance of occurring, which would dictate a similar long-run frequency of .5. Using Berkovitz denotation, this gives us $Ch_{SB}(C)=.5$ and $Ch_{SB}(\sim C)=.5$. We also know that the chances of C and ~C without B are 0, giving us $Ch_{S\sim B}(C)=0$ and $Ch_{S\sim B}(\sim C)=0$. By the law of large numbers, we can also derive the long-run frequency of C* in the reference class of type B events, giving us $F_{s*}(C^*/B^*)=.5$. We can translate Horwich's requirement for a correlation P(C.B)>P(B).P(C) to $F_{s*}(C^*.B^*)> F_{s*}(B^*)\ F_{s*}(C^*)$. From this we can determine the long run frequency of C* and the long run frequency of C* given the occurrence of B* is .5. This would give us $F_{s*}(C^*)=.5$ and $F_{s*}(C^*/B^*)=.5$ which would give us P(C)=.5 and P (C.B) =.5. While we cannot determine $F_{s*}(B^*)$ or P(B) if it has a frequency of 1 then $F_{s*}(C^*/B^*)= F_{s*}(B^*)\ F_{s*}(C^*)$ if it is less than one then $F_{s*}(C^*/B^*)> F_{s*}(B^*)\ F_{s*}(C^*)$.

The second tenet of Horwich's argument P(B.F|C) = P(B|C)P(F|C) put into Berkovitz's denotation gives us $F_{s*}(C^*\&B^*/A^*)= F_{s*}(B^*/A^*)\ F_{s*}(C^*/A^*)$. In order to figure out if this tenet fails, we can first find $F_{s*}(B^*/A^*)$. This requires us to answer the following question: Given all cases in which A occurs, how many also have B occur, or given all cases in which Joe finds the magic coin, how many also have Joe flipping the magic coin? The answer to this question is all of them, giving us $F_{s*}(B^*/A^*)=1$. We can next look at $F_{s*}(C^*/A^*)$ This requires us to answer the following questions: Given all cases in which A occurs, how many also have C occur, or given all cases in which joe finds the magic coin how many also have the coin have land heads? The answer to this question is all of them, giving us $F_{s*}(C^*/A^*)=1$. Lastly, we can find $F_{s*}(C^*\&B^*/A^*)$ We can figure this out by answering: Given all cases in which A occurs, how many have both B and C also occur. Since we know that F_{s*} (C*/A*)=1 and F_{s*} (B*/A*)=1 we can determine in all cases in which A occurs both B and C will also occur giving us F_{s*} (C*&B*/A*)=1. We can see here that Horwich's second tenet F_{s*}(C*&B*/A*)= F_{s*} (B*/A*) F_{s*} (C*/A*) succeeds giving us a correlation between events B and C screened off by a subsequent event A. However, if we examine F_{s*} (C*/B*) or the long-run frequency of C, given the occurrence of B. Which we can calculate by asking, given all cases in which B occurs, how many also have C occur, or given all cases in which joe flips the magic coin does the coin travel back in time and lands heads? Since we know this is also a deterministic relationship, this results in F_{s*} (C*/B*)=1 as opposed to .5 meaning that even if F_{s*} (B*) is 1 we would still get F_{s*} (C*/B*)> F_{s*} (B*) F_{s*} (C*). This would mean that Horwich's argument still succeeds in showing that a correlation holds between bilking attempts and foiling events. Furthermore, this correlation is only screened off by a subsequent event A. This violates the principle of V correlation and results in Horwich's ascription of this coincidence as improbable.

3.5 Improbable Coincidences

Horwich states that backward time travel would "involve an endless string of improbable coincidences" (Horwich 1987 p 123). Horwich applies the term improbable due to the causal structure of the coincidence violating the principle of v correlation. He states that we do not see these types of coincidences where a later cause C screens off the correlation. Horwich, in accordance with Dowe, this improbability is in terms of frequencies. That is, we do not see the occurrence of correlations of this type, and therefore, they have a low frequency of occurring, giving him his notion of improbability. However, Nick Smith argues against this notion of improbability in their paper "*Bananas Enough for Time Travel".* Smith argues that

Horwich's ascription of these coincidences as improbable is a mere *de facto* feature of our region of the world. He gives the following example to draw out this argument:

> “Imagine someone attempting to roll ten tomatoes across Parramatta Road at two second intervals, starting at some randomly chosen time. In the olden days, this would have been a coincidence if even one of the tomatoes had failed to reach the other side. Nowadays, however, it would be no coincidence if all the tomatoes were squashed. Squashing's are no longer coincidental because they are no longer improbable; they are no longer improbable because there are more cars on the road nowadays”
> -(Smith, 1997, p.368-369)

Smith finds this example analogous to Horwich’s argument. The correlation between tomato rolling attempts and squashings is taken to resemble a correlation between bilking attempts and foiling events. Similarly, the common cause of backward time travel is replaced by the common cause of an increase in the number of cars. Smith claims when we infer from a lack of observation that a phenomenon is improbable, this inference is indexed to a specific context. Smith states, “We can, however, draw no conclusions concerning the frequency with which the phenomena will occur in contexts unlike those in which we made the observations” (Smith, 1997, p.370). We can see this in the case above, since in the context of the olden days, tomato squashings were improbable due to a lack of cars. In the present context, however, due to an increase in cars tomato squashing's are no longer improbable. Similarly, contexts that involve backward time travel with bilking attempts and coincidences differ from those in which Horwich's observations are made. Thus, his ascriptions of coincidences as improbable fail to serve as a basis for his conclusion on the improbability of time travel.

3.6 Conclusion

In the first chapter of my thesis, we examined the concepts of chance and frequency as used by Berkovitz and Mellor. We then examined Mellor's argument for the impossibility of causal loops and Berkovitz's response. Giving us the following two claims. First, the long-run frequency of events in a causal loop is determinately one except for cases of preemption and overdetermination. Second, if an event in a causal loop is ascribed an indeterminate chance, there will be an inequality between the chance and long-run frequency, which will dictate the failure of the frequency principle.

We begin Chapter 2 by examining the bilking argument and the auto-infanticide argument. We then argue that these temporal paradoxes can be coherently modeled in the context of causal loops instead of Mobius loops. From this, we find that the bilking and auto-infanticide arguments fail due to the necessitation of foiling events in causal loops. We then explain how this necessitation is due to foiling events having determinately biased reference classes resulting in their ascribed frequency of 1.

In the last chapter, we examine Horwich's argument for the improbability of backward time travel and Dowe's reformulation. Allowing us to examine the argument in the context of Berkovitz's biased reference classes, we find Horwich's argument to be sustained upon examination. In our last section, however, we examine Smith’s argument against Horwich, which finds observational inferences to be context-sensitive, resulting in the failure of Horwich's conclusion for the improbability of backward time travel.

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