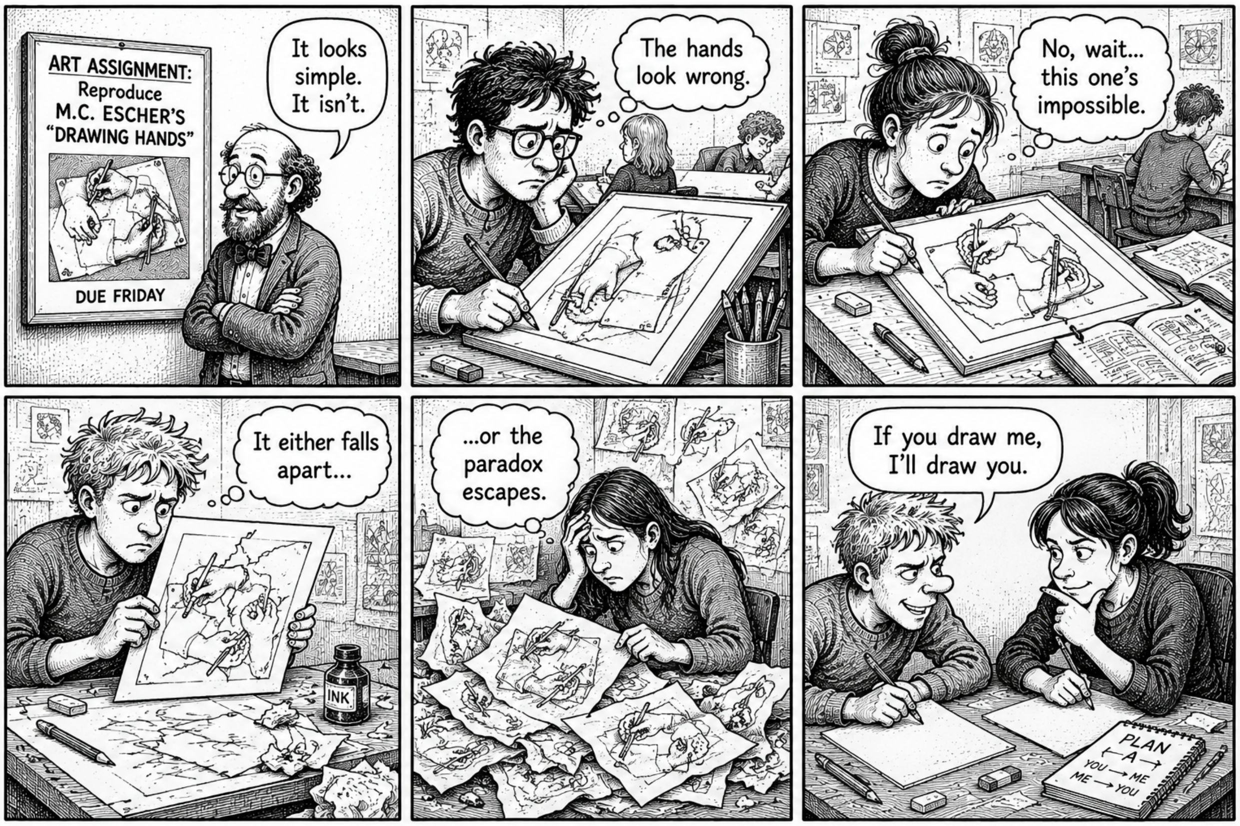
Chapter 16

“Bowtie”



Art Class

The Setup

Consider a thought experiment. Assume nature allows the construction of an FTL channel, causal signaling over a spacelike interval. We don't need a very capable one, let it be limited to two bits. Let there be two of them, long enough and with Poincaré rotations sufficient that each can send any of those four messages backwards in time in the lab frame by one second. Four messages, 00, 01, 10, & 11.

Couple the receiving end of each (earlier in time) to the sending end of the other (later in time) via a conventional timelike communication channel. In the lab frame, let the Poincaré rotations be of opposite values, so spacelike intervals cross at their midpoints, and further let the world lines of the two timelike intervals be vertical. Visually, this creates a symmetric *bowtie*, a loop in spacetime.

At each end of this bowtie are observers, who have independent choices of what to send. They may select to make manual choices, using their free will, or they may choose to delegate their choices to a computer program. The input to this program will be whatever the observer receives, and the output of this program will be what the observer is to send. Imagine that this is automated for, say a hundred runs, something long enough to generate good statistics.

This setup is quite flexible allowing several different experiments to be performed with it. Just change out the algorithm in the computer program. For a hundred runs, each observer receives 100 messages and sends 100 messages. Each keeps a detail record of what they received and what they sent. At the end of each run, the sent and received lists will be compared, analyzed for correlations.

The Experiments

There are a handful of basic experiments that can leverage this setup. Let the observers be Alice and Bob, as is the tradition. Here is the list of experiments to be analyzed.

1. Each observer programs their computer to send a random message. *Uncoupled*.
2. One observer sends a random message via computer program, the other echoes it. *U-turn*.
3. Either both observers echo, or both observers invert the received messages. *Indeterminate*.
4. One observer faithfully echoes, but the other only echoes messages 00 & 11, while inverting messages 01 & 10. This creates a *conditional paradox*.
5. One observer echoes the received message, the other inverts it: a *classic paradox*.
6. The observers chose to echo or invert, they try to do so independently. *Choice*.

Can we draw conclusions about what the correlations should look like? It is after all a thought experiment.

Case 1: Uncoupled

Each observer will receive a list of random messages and send a list of random messages. Bob's receive list will match Alice's send list, and Alice's receive list will match Bob's send list. Since they are duplicates, keep either one, delete the other. Call the kept lists the R (right) list and the L (left) list, respectively. However, the R & L lists will not be correlated. Each was generated by independent causal methods. This case merely confirms the assumption behind this thought experiment, that two functional FTL channels have in fact been set up. In this case, the two FTL channels are *uncoupled*.

The computer programs can use pseudo random number generators (pRNG), a deterministic algorithm that produces values which pass the standard statistical tests for randomness, or they could use nondeterministic hardware-based quantum random number generators (qRNG).

Case 2: U-turn

This case modifies the first by asking one observer, the passive observer, to echo what they receive. The other observer, the active observer, continues to generate either a pRNG list or a qRNG list. The active observer will now receive a list that matches what they are about to send, regardless of whether the list was pseudo random (pRNG) or truly random (qRNG). The received list is predictive. Now the L and R lists do match. To put it in the disreputable language of ESP, it is acting like a *precog*.

If the passive observer changes to inverting what is received, then the active observer receives an anti-precog list. Just as predictive, just negatively correlated instead of positively correlated.

Case 3: Indeterminate

In this case the observers either both echo or both invert the messages they receive. There are, therefore, *no* inputs to the bowtie. The pair of spacelike causes and the pair of timelike intervals form a fully closed causal loop in spacetime with no inputs, a loop that is nonlocal, and fully self-referential. The expectation is that all four messages will occur with equal frequency, and their distribution will be truly random, the kind we find in quantum physics and in game theory, but nowhere else. If more than a thought experiment, if ever realized in the lab, the engineering particulars of the FTL channels might require some fine tuning to achieve equal 25% odds for each of the four messages, but this step should be regarded as part of the calibration phase of the experiment.

If this expectation is violated, then the next most likely outcome is only one message, maybe 00, or maybe 11, or maybe 10, or, well you get the idea. Without technical details for the FTL channels, there is no apriori reason to expect a particular single value.

If both observers echo, then the L and R lists match, perfect correlation, if they both invert, then the L & R lists anti-match, perfect anti-correlation. In either case, the setup has become a rather extravagant qRNG. This observation suggests a potential connection between self-reference and the intransigent randomness of quantum systems.

Note the implied solution to the Bootstrap Paradox (also called the Ontological Paradox). In this paradox, a time traveler, object, or signal, has been created without an origin. Information has been created out of nothing. But in this case, the information is *random*, not structured. Entropy rules.

Case 4: Conditional Paradox

This is the interesting case, some specific messages are echoed, others inverted. The active observer inverts half the messages, say 01 and 10. If a 01 is received, a 10 will be sent, which means a 10 was received, except that it wasn't. Ditto for receiving 10. These cases are causal contradictions. The easiest way for nature to avoid the paradox is to simply never generate either 01 or 10, but to generate only 00 and 11. The odds that the bits will match are now 100%, when before it was 50%. The odds of getting 01 or 10 are now zero when before they were 25%. The odds of getting 00 or 11 are now 50% when before they were 25%. The odds have changed. We have been able to change the statistics of a quantum system without interacting with it. All that was changed was some code.

This adds an interesting twist to the Ontological Paradox, some outside agency has hemmed in the indeterminacy to constrain what is causally consistent. Entropy compressed. Now information has been injected into the self-referential loop. Maybe Marty McFly[1] really can get his parents-to-be to fall in love with each other, but perhaps only if he is outside the loop.

The program that achieves this will necessarily contain an `if` statement: if the message 00 or 11 is received, call the subroutine that echoes it. If not, call the subroutine that inverts it. Note that

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[1] The "Back to the Future" movie.

the invert subroutine will *never* be called. It will never run. It does not affect reality by being executed, the normal causal nature of a computer program. It affects reality because it *exists*.

Let that sink in for a minute. An effect was achieved without a force, without a field, without a minimization principle. Not a hammer, just a thought. Replace that subroutine with the echo subroutine and it will now get called, half the time in fact. Gisin[2] has argued that nonlocality requires a new third type of causality; his cup runneth over.

A conditional paradox affects a portion of reality that is spacelike separated from it. It is a nonlocal cause. If free will is a legitimate concept, if it is not an illusion of chaotic systems, or evolutionary adaptation, or chance, then there must be a basis for it in physics. We will, regrettably, lay this bright bauble down, and with stern self-discipline avoid the digression, but this surprising development will be revisited in a later chapter. I promise.

Case 5: Classic Paradox

It would seem this case must rule out FTL, but no experiment is perfect. All communication channels have some noise. There is always a finite chance that noise will overwhelm one of the FTL legs of the bowtie. For example, a 01 might get corrupted into 00 on the left-to-right channel, and the 00 corrupted to a 01 on the right-to-left channel. The correlation of the sent and received messages is violated, but that is always the case when noise swamps signal. It is likely that as the number of bits is increased, but only messages with all zeroes or all ones are echoed, that noise starts to dominate, and the odds of all zero or all one messages decrease from 50%. As this deviation increases, the correlation between the L & R lists decreases. This would make an effective SNR test. The larger the ratio of inverted messages, the flakier the system becomes. *Some paradoxes are stronger than others*, but in physics they are all conditional. A quantum paradox always contains a loophole, it is only at the classical level that paradoxes are intractable.

Case 6: Choice

In this case the observers abandon their computer programs, and each *chooses* on each communication whether to echo or invert. When they make the same choice, the bowtie is indeterminate, and all messages are equally likely. The L & R lists either match or anti-match, perfectly. When they don't make the same choice, the bowtie is paradoxical and becomes dominated by noise. The L and R lists become uncorrelated.

Can we assume the observers have free will, or do they just think they have it? If Alice chooses to invert, does this force Bob to invert? Alice and Bob are symmetric. Is it possible the two observers always make the same choice? Is one will stronger than another? Can the strength of a will be quantified? We will revisit this topic, when we know a little more about self-reference, but bright bauble be dammed, wouldn't it be something if 'time travel' is intimately connected with free-will? That should keep the philosophers busy.

The odds that both observers always make the same choice would be astronomical. Such a result would be miraculous. More meat for the philosophers, and now maybe even some for the theologians.

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[2] Need reference.

Summary

The bowtie thought experiment yields surprising results. Foremost being that temporal paradox is not a valid argument against spacelike causality. Don't even need QTP.[3] We've made the world safe for spacelike causality.

The second surprise, receiving information from the future, is sci-fi in its purest form. But if given working FTL channels, this case cannot be denied. It's uncomfortable from the current dogma, but the supposition that it becomes problematical if the loop is closed appears to be unfounded.

The third surprise is how easily the Ontological Paradox (it should be called the Ontological Indeterminacy) is resolved. The implication is that whatever is logically consistent is equally likely, but if inconsistencies can be imposed, then the odds change.

That's the fourth surprise, conditional paradoxes, where outside influences can affect the statistics of a quantum system, by their mere *existence*. Think of the technological possibilities.

The fifth surprise is that all physical paradoxes will have a signal to noise ratio, which means they are all conditional paradoxes, it's the impreciseness of natural language that makes them appear to be classic paradoxes. Logic may still have some work to do (let loose imaginary truthvalues) but physical reality seems to have been saved. Noise makes the universe safe from paradox, indeterminacy generates randomness. It's a rather elegant marriage.

The sixth surprise is the implication that time travel may have something to say about free will. Are you kidding? Who saw that coming? Or have we, in our excitement, gotten ahead of ourselves. We don't yet have a formalism for how to construct an FTL channel out of quantum physics, and as we'll see shortly, there are plenty of failed attempts to do so. But the strongest argument against it, temporal paradox, has been vanquished. That's quite a surprise. It is also progress.

Proof that this 'insight' is more than merely speculative is going to require hard work, inventive inquiry, and some technical formalisms. To be continued…

Coda

Self-reference doesn't have to occur in spacetime, it can occur simply in space, and doesn't require FTL. Let's ground the above thought experiment in something less speculative, digital circuits.

Echo Version of the OI

As a warmup, first consider a single bit system with left and right echoers. This can be achieved by simply placing two BUF gates in sequence, as shown in Figure 1. This circuit is stable if both outputs are true, but also stable if both outputs are false. Note that there are no inputs, it is a closed causal loop. This is the digital analog of the Ontological Paradox which should really be called the Ontological Indeterminacy (OI). More accurately one of many, but this one is the best analog with the bowtie, when both observers echo what they receive.

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[3] Darn.

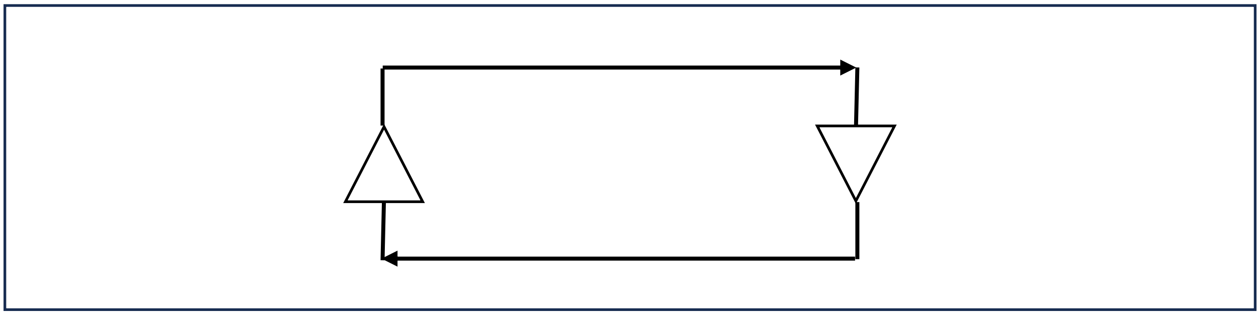

Figure 1 – **Ontological Indeterminacy, Echo Version**: Two BUF gates in sequence in a self-referential circuit. The outputs are correlated.

For intrepid readers unfamiliar with digital circuit diagrams the BUF gate outputs whatever is at its input; if 0, it outputs 0, if 1 it outputs 1. It's about as easy as it gets. False is usually mapped to 0 and true is mapped to 1. If Alice observes true, so will Bob, and if Alice observes false, so will Bob – correlated.

Invert Version of the OI

When both observers invert, the digital circuit equivalent contains two NOT gates as shown in Figure 2.

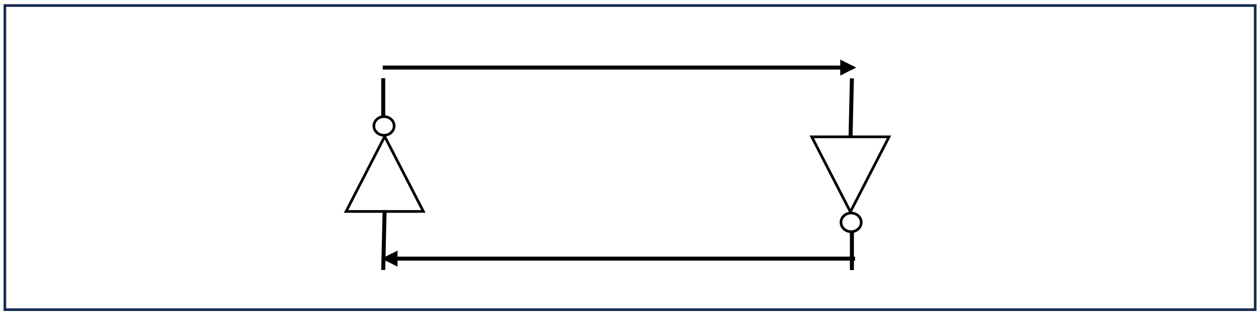

Figure 2 – **Ontological Indeterminacy, Invert Version**: Two NOT gates in sequence in a self-referential circuit. The outputs are anti-correlated.

The NOT gate inverts whatever is at its input, 0 => 1, 1 => 0. If the input is false, the output is true and if the input is true, the output is false. If Alice observes true, Bob will observe false, and if Alice observes false, Bob will observe true – anti-correlated.

The 64-dollar question is if these circuits, upon power up, will display determinate or random behavior. Off the shelf products will generally display determinate behavior. These gates are designed to be a simple as possible, they are basically open-ended high-gain analog amplifiers, intended for ultra-fast switching suitable for use in digital computers. They are not designed as analogs with formal logic.

However, which determinate value appears can depend on the process node, manufacturer, voltage, temperature, local capacitance, inductance, etc. With a little perseverance it is often possible to tune the environment around such circuits, so they exhibit random behavior.

Liar's Paradox

The conditional paradox mentioned above will require a fuller development of these tools, but digital circuits will show up again as part of the discussion on imaginary truthvalues. We can, however, even at this point in the formal development, get a foretaste of the classic paradox. Figure 3 shows the 2-stage Liar's Paradox.

Until then, we'll restrict ourselves to one more circuit, the Liar's Paradox, shown in Figure 3.

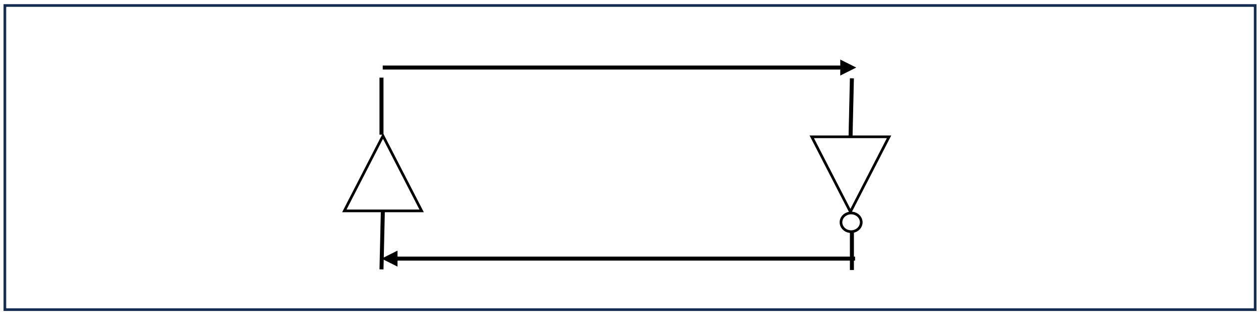

Figure 3 – **Liar's Paradox, 2-Stage Version**: One BUF gate and one NOT gate in sequence in a self-referential circuit. There are no Boolean truthvalues which are consistent with this circuit, its behavior, at this stage of formal development, is undefined.

In the two-bit FTL channel assumed in the thought experiment, the equivalent digital circuit is more complicated,

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