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Time-Reversed Information Transmission

Lila L. Gatlin

Statistics Department, University of California, Berkeley, California 94720

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Tolman's paradox forbidding time-reversed information transmission is nonexistent and rests only on our ingrained thought processes involving hidden, unnecessary assumptions. When the assumption of a passive channel is removed, the paradox cannot be derived and information can flow intermittently or nondeterministically from the future over a simple computer with at least one independent decision-making component.

A number of workers have discussed the apparent paradox arising from the concept of time-reversed information transmission. This is sometimes called Tolman's paradox and may be expressed in many ways. Benford, Book, and Newcomb (1970) use the following form.

Let two observers, A and B, enter into the following contract: A will signal B at say three o'clock if and only if A does not receive a signal from B at one o'clock. All messages flow backwards in time and B receives and relays at some convenient intermediate time, say two o'clock. It is useful to have a notation for this information flow. Let $T(A^m \to B^n)$ be the proposition that information flows from A to B where the exact times of transmission and reception are denoted as superscripts. The standard symbols $\Rightarrow$, $\neg$, and $\Leftrightarrow$ mean "if...then," "not," and "if and only if," respectively. The contract then reads

$$T(A^3 \to B^2) \Leftrightarrow \neg T(B^2 \to A^1) \tag{1}$$

In words, A transmits a message to B at three o'clock if and only if A does not receive a message from B at one o'clock. Benford, Book, and Newcomb then claim that from this situation the genuine paradox can be derived that information transmission takes place if and only if it does not take place.

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However, it is well to be aware that this contradiction cannot be derived without the somewhat hidden assumption that B acts as a passive information channel which can neither initiate messages nor refuse to relay them. Let us derive the contradiction:

$$T(A^3 \rightarrow B^2) \Rightarrow T(B^2 \rightarrow A^1) \Rightarrow \neg T(A^3 \rightarrow B^2) \tag{2}$$

$$\neg T(A^3 \rightarrow B^2) \Rightarrow \neg T(B^2 \rightarrow A^1) \Rightarrow T(A^3 \rightarrow B^2) \tag{3}$$

$$T(A^3 \rightarrow B^2) \Leftrightarrow \neg T(A^3 \rightarrow B^2) \tag{4}$$

The contradiction, equation (4), does indeed follow from (2) and (3); but note that in the first step of (2) it is assumed that B must relay all messages received from A. Benford, Book, and Newcomb state this explicitly: "B sends a message to reach A at one o'clock immediately on receiving one from A at two o'clock." Then in the first step of (3), we must assume that B will not transmit to A unless B does in fact receive a message from A, i.e., we are assuming that B cannot initiate messages on its own. Thus the derivation of the contradiction hinges on the assumption that B is a passive channel without any decision-making capability.

It is instructive to see what would happen under the contract

$$T(A^3 \rightarrow B^2) \Leftrightarrow T(B^2 \rightarrow A^1) \tag{5}$$

If we let A initiate messages, B is a passive channel which transmits if and only if it receives messages from A. If we let B initiate, A becomes the passive channel. But as the contract is stated, neither A nor B can initiate. They are both passive channels and therefore nothing happens. Communication is completely blocked and it is easy to see why Benford, Book, and Newcomb chose equation (1) for the form of the contract.

There are, in fact, only two other forms of the contract algebraically possible:

$$\neg T(A^3 \rightarrow B^2) \Leftrightarrow \neg T(B^2 \rightarrow A^1) \tag{6}$$

$$\neg T(A^3 \rightarrow B^2) \Leftrightarrow T(B^2 \rightarrow A^1) \tag{7}$$

It is easy to see that (6) is equivalent to (5) and (7) is equivalent to (1). Hence all possible forms of causal contract between A and B are covered.

If we eliminate the concept of a passive or automatic channel, which also eliminates the concept of contracts, we can no longer make deterministic or causal "if...then" statements such as in all our equations. Therefore let us simply regard both A and B as independent decision making entities. Perhaps A will transmit to B, $T(A^3 \rightarrow B^2)$, and perhaps B will decide to return the signal, $T(B^2 \rightarrow A^1)$. Then we may have a genuine information flow backwards in time where the message which A sent out at three o'clock arrives back at A at one o'clock, the much discussed "signalling to one's past" or "closed causal cycle" (Newton, 1970). This is not at all, in principle, impossible; but the only way it can occur is if we remove strict causality from the B linkage and make B's response nondeterministic. In this sense the label "closed causal cycle" is a misnomer.

Other workers have arrived at the same conclusion that information can, in principle, be transmitted backwards in time; but in this work other problems arise which are sometimes more unpalatable than the original paradox. For example, Wheeler and Feynman (1949) have built a mechanical model of a machine programmed to blow itself up at two o'clock if and only if it receives at one o'clock a signal which was transmitted at three o'clock. They show from the solution of their dynamical equation that the signal is so weak and ambiguous, just at the threshold needed to activate the detonator, that the machine can possibly emit a weak signal just before being destroyed.

This is in essence a denial that information was transmitted backwards in time. Peres and Schulman (1972) have made this evasiveness clear by inserting a decision maker in the model at 1:30 o'clock to resolve the ambiguous signal. If this decision maker, which may be either a random coin flipper or a human mind with "free will," decides not to destroy the transmitter, then a strong signal will be emitted at 3 o'clock. The machine will then transmit at 3 o'clock clear instructions to self-destruct at 2 o'clock. The paradox is reinstated.

Peres and Schulman assume that their decision maker has the property of randomness in the sense of being unpredictable, yet their mechanical model yields an equation, which in conjunction with a few simple experimental measurements of initial conditions, can predict deterministically how the coin will fall "even if the coin has not yet been minted." Thus we simply have a new form of the paradox, namely, that random is not random.

Since we are dealing with a paradox in information transmission and since the definition of information is intimately connected with the concept of randomness and conversely (Chaitin, 1975), it is not surprising to see Tolman's paradox restated in terms of randomness. From the viewpoint of information theory (Shannon, 1949), the only essential conceptual elements of the problem are the source or transmitter, the channel, which must always exist if a message is to be transmitted, and the receiver, which may even be in the same information-processing system as the source. The essential question is the nature of the channel.

Since the mechanical model of Wheeler and Feynman denied the paradox by making the signal ambiguous, the function of the decision maker inserted by Peres and Schulman was to resolve the ambiguity of the signal, thus reinstating the paradox. In a simple channel where the signals are unambiguous to begin with, such as our original example, the function of a decision maker is to make the channel nonpassive resulting in the resolution of the paradox. Thus decision-making components can remove or reinstate the paradox, depending on the initial condition of the channel. In the Peres and Schulman model the introduction of a second, independent decision maker in the channel will resolve the paradox as in our original example by making the channel nonpassive. Hence their problem with the concept of randomness is easily avoided.

Therefore we have shown that a necessary condition for time-reversed information transmission is a nonpassive channel which in turn requires at least one decision-making entity in the channel with no causal linkage to the source. Under such a condition the paradox cannot be derived. The nature of this necessary condition is such as to require that no sufficient condition exists. We might describe this system as a simple computer with at least one decision-making component rather than a passive information channel. The conclusion is that at least such a simple computer is required to transmit messages from the future.

It is clear that all previous work on this problem, with the possible exception of that of Peres and Schulman, has been based on the assumption of a simple passive channel governed by deterministic equations. The paradox is not inherent in the nature of the information concept but arises from our deeply ingrained thought processes which are still rooted in the paradigm of a deterministic world view in space-time as discussed by Weissmann (1978).

Thus although it will never be possible to design a communications system which transmits messages from the future upon request from the designer (for example, we cannot program self-destructing machines in the reversed time mode), this alone does not exclude the possibility that intermittent unrequested messages from the future may sometimes reach a simple computer or, particularly, living organisms, which are masterful information-processing systems (Gatlin, 1972).

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REFERENCES

Benford, G. A., Book, D. L., and Newcomb, W. A. (1970). *Physical Review D*, **2**, 263.
Chaitin, G. J. (1975). *Scientific American*, **232**, 47.
Gatlin, L. L. (1972). *Information Theory and the Living System*. Columbia University Press, New York.
Newton, R. G. (1970). *Science*, **167**, 1569.
Peres, A., and Schulman, L. S. (1972). *International Journal of Theoretical Physics*, **6**, 377.
Shannon, C. E. (1949). *The Mathematical Theory of Communication*, University of Chicago Press, Urbana, Illinois.
Weissmann, G. (1978). *International Journal of Theoretical Physics*, **17**, 853.
Wheeler, J. A., and Feynman, R. P. (1949). *Reviews of Modern Physics*, **21**, 425.