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Entropy and Subtle Interactions

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"(Classical thermodynamics) is the only physical theory of universal content which I am convinced will never be overthrown ..."—Albert Einstein (Klein, 1967)

Abstract—Entropy considerations are used to determine the types of subtle interactions (SI), or psi phenomena, that are consistent with the second law of thermodynamics. The analysis is preceded by a short tutorial on entropy and the second law of thermodynamics. For a coherent advanced (retrocausation) signal to exist, it would conflict with the second law in forward time because it would require a reduction in the entropy of background fluctuations from which the wave appeared to condense. The compensating increase in entropy of the source would occur only later. For advanced phenomena that require only a quantum trigger rather than a coherent wave, there is no conflict with the second law. These concepts are generalized to include all SI, even if they are not retrocausal. Examples of allowed SI are described between living beings and (i) other animate systems, (ii.a) electronic random event generators and (ii.b) non-electronic inanimate systems, and also between (iii) one inanimate system and another.

Keywords: psi—entropy—thermodynamics—retrocausation—precognition—psychokinesis—remote perception—clairvoyance—telepathy—advanced waves—paranormal—psychic—retroactive—retrograde

I. Introduction

This paper considers subtle interactions (SI), where the term SI is used here to include psi phenomena such as precognition, psychokinesis, remote perception, and telepathy, and also anomalous interactions among inanimate systems. Experimental evidence for such phenomena continues to mount (Radin, 1997, and references therein). With repeated corroboration of the experimental evidence, the desire to establish physical theories that accurately describe the phenomena becomes more pressing. Before launching new theories, a fundamental question to ask is whether SI phenomena are in line with currently accepted physics, or whether new theories that go beyond or even contradict currently accepted physics are required. According to Schmidt's "weak-violation hypothesis" traditional physical laws are obeyed except that SI affect the outcome of ostensibly random quantum events (Schmidt, 1987). Fundamental to traditional physics is the concept of entropy and the second law of thermodynamics. In this paper, I propose a way to apply the second law to SI to gain insights into whether SI are consistent with traditional physics and to aid in the design of fruitful SI experiments.

After an introduction, I present a brief tutorial on the concept of entropy and the second law of thermodynamics for the general audience who may be unfamiliar with these. This is followed by a discussion of how the second law can be applied to advanced signals (retrocausation) in particular and SI in general, followed by a description of quantum triggers. I divide SI into classes and discuss which types of SI are consistent with the second law. Then I describe which types would be inconsistent with the second law, and conclude with a discussion of the consequences of this analysis.

On one hand, several theories that contradict the second law have been proposed to explain SI. One such theory is that causation emanates from an event in both forward and retrograde time (Feinberg, 1975). Another theory makes use of the concept of negative entropy as an organizing force in SI (de Beauregard, 1975). On the other hand, the second law of thermodynamics is such a fundamental part of accepted physics that it would take a great deal of evidence to overthrow it (see Einstein's statement at the beginning of this paper). Let us see if SI can be described in a way that preserves the second law of thermodynamics, and how we can gain insights into SI experiments from this analysis.

II. Entropy and the Second Law of Thermodynamics

Entropy is a measure of the number of accessible states, i.e., options, available to a system (described in any statistical thermodynamics text, e.g., Landau & Lifshitz, 1980). It is sometimes described loosely as a measure of the disorder of a system.

The concept of entropy applies only to large systems, but it can be illustrated using a simple example. In Figure 1, System A consists of one marble and three positions. The system is divided such that the left-hand section, having two positions and one marble, is separated by a barrier from the right-hand section, having one position and no marbles. As shown, there are two possible options for the system. System B is like System A, but with the barrier removed. It has more options, as shown. The entropy of System B would be larger than that of System A (if the entropy concept applied to such small systems).

The second law of thermodynamics may be stated as follows:

Rule 1: The entropy of a closed[1] system cannot decrease as time progresses.

The entropy can only remain the same or increase. This is illustrated in Figure 2. In the top left-hand picture, a series of dark marbles lie separated from a series of light marbles. As time progresses, the marbles intermingle until, in the lower left-hand picture, they are randomly distributed. In the top right-hand picture, a hot metal bar had been brought into contact with a cold metal bar. As time passes, the heat spreads from the hot to the cold side until the temperature

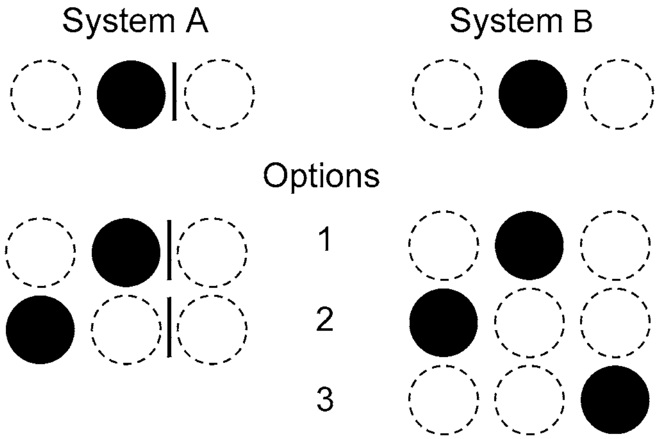

Fig. 1. Two systems of a black marble and empty positions, demonstrating the concept of entropy. By removing the barrier from System A to form System B, the marble has more possible locations, and the system has more configuration options. This corresponds to increased entropy.

becomes uniform throughout. In both lower pictures the entropy has attained a maximum. The direction of time's arrow is clear: in comparing an upper picture with a lower picture, there can be no mistaking which situation was the earlier one.

III. The Second Law of Thermodynamics Applied to Advanced Signals

It is possible to reduce the entropy of a system. For example, consider the case of a person encountering the marbles in the lower left-hand picture of Figure 2. She (the "agent") tidies up the marbles (the "receiver"), leaving them in the state shown in the upper left-hand picture. The entropy of the receiver has been reduced, but at the expense of increasing the entropy of the agent by at least an equal amount, through the use of chemical energy (food) and the production of waste heat and materials. In this way the entropy of a receiver may be decreased if the loss is compensated for by the increase in the entropy of the agent. The entropy of the combined system composed of the receiver and the agent never[2] decreases.

In a retrocausation situation, the effect is registered by the receiver *in advance of* the action by the agent. If the entropy of the receiver decreases, then the compensating increase in the entropy of the agent occurs later. Thus there is a net decrease in the entropy of the combined system for a period of time. This is in conflict with the second law of thermodynamics. Therefore, the following rule for advanced signals must be in effect if the second law is to be maintained:

Rule 2: The entropy of a receiver cannot be decreased by an advanced signal.

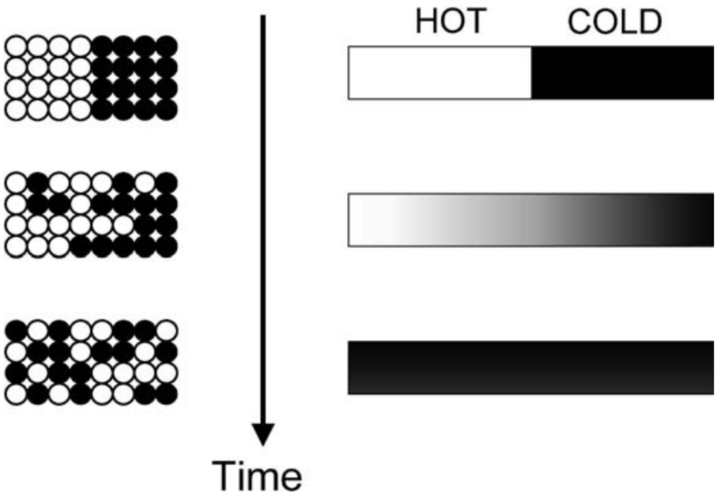

Fig. 2. Illustration of the second law of thermodynamics. The left-hand side depicts a set of marbles intermingling over time. The right-hand side depicts a metal bar in which temperature equalizes over time. In both situations, the direction of time's arrow is clear.

IV. The Second Law of Thermodynamics Applied to General SI

IV.a. Time Dependence

A wide range of SI experiments have shown that SI operate no matter whether the agent acts before, at the same time as, or after the receiver. Below I describe four examples.

1. Random number generators: The statistical distribution of the output of random number generators can be affected by the intention of a participant. It has also been found that this effect is not dependent on whether the intention is applied at the same time as the random number generator is operating, several days beforehand, or afterwards (Dunne & Jahn, 1992; Jahn et al., 1997).
2. Remote perception: In one form of remote perception, one person (the receiver) attempts to describe the remote location of another person (the agent). A wide range of experiments has shown that the accuracy of the description exceeds random chance. The remote perception is not attenuated with increasing time interval between the action of the receiver and that of the agent (Dunne & Jahn, 2003).
3. Random mechanical cascade: In a random mechanical cascade (also known as a Galton's desk), a series of pegs deflect falling polystyrene balls that ultimately land in a row of bins. The distribution of balls that

have landed in the bins can be shifted by operator intention during the fall of the balls (Dunne et al., 1988). Comparable results are found when the intention is applied at a separate time (Jahn et al., 1997).

4. Pre-recorded clicks: H. Schmidt demonstrated a retroactive psychokinesis effect using stereo headphones connected a tape recorder (Schmidt, 1987). The tape had previously been recorded with the output of a random noise source that produced clicks in the left or right track. Schmidt found that a person wearing the headphones could use intention to affect whether the clicks were audible dominantly in the left or the right headphone, even though the clicks had been recorded previously. He used the results to support his ‘‘equivalence hypothesis,’’ that such effects worked no matter whether the receiver (person) acted before or after the agent (random noise source).

For any psychokinesis experiment that produced a positive result, to my knowledge all attempts to measure retroactive psychokinesis were also successful. In developing Rule 2, I considered the case of advanced signals in which the action of the receiver precedes that of the agent. From the retroactive psychokinesis results, we see that receiver and agent effects do not depend on the temporal order of events. Therefore I propose that Rule 2 may be generalized to become Rule 3, which applies to SI receivers even if they are not receiving advanced signals.

Rule 3: The entropy of a receiver cannot be decreased through SI.

IV.b. Precognition versus Psychokinesis

It is often difficult to distinguish precognition from psychokinesis. In psychokinesis, the agent produces a reaction in a receiver. For example, if one chooses to affect the output of a random event generator, the agent is the person and the receiver is the random event generator. In precognition, the receiver perceives an event produced by an agent at a later time. For example, if one perceives the output that will be produced by a random event generator, the agent is the random event generator and the receiver is the person. An observer cannot discern which of these two examples is taking place, the precognition or the psychokinesis, i.e., which entity is the agent and which is the receiver.

A participant might believe that he knows. For example, he may be convinced that he is sensing and not causing a particular future event, i.e., that he is the receiver and not the agent. This sensation is subjective, and it is possible that it conflicts with the sensation of the other party who believes that she is the receiver and not the agent. The act of sensing an event may well be one and the same as the act of influencing it. By analogy with quantum mechanics, the act of measuring a phenomenon also affects it.

In the initial application of the second law of thermodynamics (Rule 1) to SI in the previous section, a decrease in the entropy of the receiver could not be compensated for by a rise in that of the agent because the agent acted later. Because of this delay in compensation, the entropy of the receiver could not decrease (Rule 2). I used the experimental observations that SI do not depend on the temporal order of events to extend the conclusion to state that the entropy of the receiver cannot decrease (Rule 3), independent of whether the phenomena result from advanced or forward-going signals. Now, because of the entanglement of precognition and psychokinesis and the related difficulty of determining which entity is the agent and which is the receiver, the conclusion may be extended further, so that both the agent and the receiver must observe the second law of thermodynamics independently. This may be stated as the following rule:

Rule 4: The entropy of neither an agent nor a receiver can be decreased through SI.

This rule has been developed to apply to precognition and psychokinesis phenomena resulting from either advanced signals (retrocausation) or retarded (normal forward-going) signals, i.e., SI in which information is transferred with the result of perceiving or affecting a remote action. The rule may be generalized further to telepathy and remote perception. In precognition, the agent and the receiver must each observe the second law no matter which operates first. Telepathy and remote perception are special cases in which they operate concurrently.

V. Triggers for SI

To be sensitive to SI, the receiver must have a means to receive the influence. The transfer cannot involve substantial energy, for if it did this energy transfer would be regularly measured. Significant energy would be required to dislodge the receiver from a stable state, and so the influence must act when it can have an effect without expending energy. This can be accomplished by influencing the outcome of an ostensibly random event, the collapse of a quantum wave function. This mode of influence has not been proven, but has been proposed by several researchers (see, for example, Houtkooper, 2002, and Schmidt, 1987).

The influence triggers an effect during what appears to be a spontaneous event. For an electronic random number generator, the random source is usually Johnson noise in a resistor. The noise is composed of thermal vibrations, which are quantized energy packets called phonons. The phonons jostle the electrons and transfer random quanta of energy to them, providing them with a distribution of energies, the average of which is determined by the temperature of the resistor. Every once in a while an electron is sufficiently jostled that it produces a spike of current or voltage in electronics connected to the resister. When this spike exceeds a particular threshold, it triggers the electronics to register a digital bit.

Such triggers can act also in non-electronic physical systems. It is not difficult to imagine events that are similar to thermal fluctuations in the resistor occurring in the neural networks of our nervous system. Spikes in these fluctuations can trigger a decision, or provide one bit of an image or piece of information. A series of such bits could produce an image or insight. In a random mechanical cascade where a series of pegs deflect falling polystyrene balls, the location where a ball comes to rest is extremely sensitive to infinitesimal shifts in the ball's trajectory. A ball can be shifted tens of centimeters by thermal fluctuations in the pegs smaller than an interatomic distance (Thompson, 2003).

Traditionally, thermal noise is considered to be purely random. Given that an agent influences a receiver in a subtle way, it is not an unreasonable stretch to surmise that this influence occurs via a thermal noise trigger. How could this function? It is known in quantum mechanics that an observation can modify the quantum state of a system. It is tempting to speculate that SI work in a similar manner, in which the act of receiving information from a system also influences that system. Such an interaction is consistent with the difficulty of distinguishing which party in the activity is the agent and which is the receiver, as noted in Section IV.b.

The sorts of single quantum event described above are microscopic. To produce large, macroscopic effects, there must be an amplification of the quantum trigger, or there must be a large number of the triggered events occurring in tandem. In the examples given above, there is amplification.

- In a random number generator, electronics connected to the noise-producing resistor amplifies the output.
- In a random mechanical cascade, the multiple bounces off pegs produce a huge amplification of microscopic shifts in the initial trajectory of the balls.
- In our nervous systems, chemical amplifiers can magnify microscopic events and raise them to the level of consciousness.

If, instead of amplifying a small number of quantum-triggered events, the macroscopic effects resulted from a large number of the triggered events occurring in tandem, there would be an associated reduction in entropy. The reason is that such a tandem (coherent) set of events could be viewed as organizing the random background fluctuations (similar to organizing the marbles in the left-hand side of Figure 2), and thus reducing the system's entropy. Therefore, according to Rule 4, this sort of a coherent triggering cannot be the source of SI; however, incoherent quantum-event triggers, which are amplified, can be. This is because the second law of thermodynamics results from the statistics of systems containing many elements; entropy is not associated with the sort of single-quantum events that have been described in this section.[3]

We have established rules that SI phenomena must obey to be consistent with the second law of thermodynamics and have gained some insight into the sort of mechanisms that could trigger SI. Now we are in a position to analyze types of SI and distinguish those that are consistent with the second law from others that are not.

VI. SI that are Consistent with the Second Law of Thermodynamics

For SI to be consistent with the second law of thermodynamics, they must proceed according to Rule 4, i.e., for each operator—agent and receiver—the entropy of the final state must be no smaller than the entropy of the initial state. There are four categories of SI, which I describe below. For each I give examples of SI experiments that can show, and in fact have shown, positive results.

VI.a. Human ↔ Human

In this category, one human serves as the agent to affect another human, who is the receiver. For ease of discussion I use the word human, but it is to be understood that the agent and receiver could also be animals, and quite possibly plants as well.

Although SI effects in humans might produce some localized decreases in entropy, the overall effect is one in which the entropy is increased, as in the case described earlier of the person tidying up the marbles of the lower left-hand picture in Figure 2. Living beings have many internal mechanisms that increase entropy, so that SI involving humans are consistent with the second law of thermodynamics.

- Precognition of world events. In many documented examples, human receivers have been affected by emotional reactions of human agents.
- Telepathy (see, for example, Sheldrake & Smart, 2003, for a recent study).
- Prayer and healing. Prayer has been shown to be effective in healing others (Harris et al., 1999).

VI.b. Human ↔ Electronic Random Event Generator

As described in the previous section, thermal Johnson noise in a resistor is an effective way to generate random electronic signals. Through SI, this noise may be considered somewhat organized, which in principle might lead to a reduction of entropy. However, to turn this signal into meaningful signals requires signal processing and amplification. The electronics required to accomplish this produce far more entropy than might be reduced in the resistor source. The result is that the net entropy of the system required to produce meaningful signals, consisting of the resistor and the associated electronics, increases. Therefore, random event generators (REGs) observe Rule 4. Several examples of REG-based micro-psychokinesis and precognition experiments are as follows:

1. Random number generators. A wide range of experiments has demonstrated changes in the output of random number generators as a result of remote human intention. A broad array of such measurements has been carried

out as part of the PEAR program (Dunne & Jahn, 1992; Jahn et al., 1997).

2. Precognition of randomly chosen displayed images. Radin has carried out computer-based experiments with a huge sample size in which the ability of operators to anticipate a displayed image is measured, both at localized sites and remotely over the internet (Radin, 1997, 2002).
3. As described earlier, H. Schmidt tested the ability of listeners to affect on which side of a pair of headphones randomly produced pre-recorded clicks were audible (Schmidt, 1987).

VI.c. Human ↔ Non-Electronic Inanimate System

Through SI, operators have been able to use their intention to influence the state of inanimate systems. In some of these experiments, the influence of the operators causes the system to move to a state that is more organized than it would have been in the absence of the influence. At first it might appear that this contradicts Rule 4, because greater organization correlates with lower entropy. Rule 4 is not contradicted even though the SI might cause the system to coalesce into a final state of lower entropy than it would have otherwise, because the state still is higher in entropy than the initial state. For example, in a random mechanical cascade, SI influence may cause the balls to fall into locations that are less randomly distributed than they would have been in the absence of the SI. However, for the cases both with and without SI, the balls fall from a state of lower entropy to a state of higher entropy. This could be illustrated by photographs of the balls taken before and after their fall through the apparatus: the final resting state would have a clearly discernable larger entropy than the initial state of the balls perched above the pegs, independent of whether the SI influence had been applied. Therefore, Rule 4 is maintained in such inanimate systems, and hence this class of human ↔ inanimate-system SI experiments can work. Examples include the following:

- Random mechanical cascade. Operators affect the final resting location of falling balls deflected by series of pins (Dunne et al., 1988).
- Pendulum decay. Operators affect the rate at which the oscillations of a pendulum decay (Nelson et al., 1994). Whether operators apply influence or not, the swinging pendulums generate air turbulence, which produces heat and hence in increase in entropy.

VI.d. Inanimate System ↔ Inanimate System

Quantum mechanics provides fertile ground for SI, including interactions that do not involve human intervention. In a double-slit experiment, particles such as electrons are fired through a mask containing two slits (described in most quantum mechanics texts, e.g., Kroemer, 1994). Because particles exhibit wave qualities, in passing through the two slits they interfere to form the peaks and valleys of an interference pattern on a screen placed at some distance behind the mask. Even when a single particle at a time is fired through the double-slit mask, it interferes with itself such that the aggregate of many such individually fired particles forms the usual interference pattern. From this we can tell that each particle has sampled paths through both slits.

If one of the slits is covered by a particle detector, the entire particle either passes through the other slit or the entire particle hits the detector and is measured, but it does pass through both slits. The particle somehow "knows" in advance if both slits are open, in which case it samples both paths, or if one slit is blocked and it must pass entirely through a single slit.

This advanced knowledge[4] has been elucidated dramatically in a variation of the double-slit apparatus described by John Wheeler (Folger, 2002). In Wheeler's variation, the double-slit is replaced by two galaxies forming a gravitational lens that focuses light emanating in two directions from a distant quasar and traveling to Earth. A particle of light (a photon) is launched from the distant star many years before it arrives at Earth. Even though the launch occurs long before its detection on Earth, the decision whether to sample both paths or only one is made based on how the photon will be registered[5] on Earth, and depends upon whether one path is blocked or light coming from both directions is allowed to interfere. In this way, Wheeler shows that reception apparatus formed today on Earth affects the launch of light from a distant body many years ago.

VII. SI that would be Inconsistent with the Second Law of Thermodynamics

It is worthwhile to investigate which types of SI would *not* be consistent with the second law of thermodynamics for the following reasons:

1. To show that the weak-violation assumption discussed in Section I is not correct, which would be the case if convincing experimental evidence were found for SI phenomena that were inconsistent with the second law. In such a case, substantial changes to our current understanding of physics would be required.
2. To serve as a guide in setting up experiments that are likely to yield positive results.

If the second law of thermodynamics holds in forward-going time for SI, then phenomena that break Rule 4 cannot occur, i.e., the final-state entropy of either the agent or the receiver cannot be smaller than the initial-state entropy. Because living beings have so many internal ways to increase their entropy, most of the potential SI that do not observe the second law are inanimate-system ↔ inanimate-system interactions. Examples include the following:

- Converging ripples. Ripples in a pond provide a graphic way to visualize retrograde time. Imagine a stone dropping into a pond producing concentric ripples that emanate outwards and eventually dissipate into random fluctuations at the water's surface. In retrograde time, this normal wave would appear as concentric ripples forming from random surface fluctuations and converging, to arrive at their center at just the right time to meet a stone emerging from the pond. In normal forward-going time, an advanced wave would form from random surface fluctuations and converge at the right time to meet the entering stone. This is the inanimate version of psychokinesis, in which the falling stone causes the advanced ripples to form, or perhaps precognition, in which the ripples anticipate the arrival of the stone. From any perspective, as the advanced ripples form and converge they represent a reduction in entropy from that of the randomly fluctuating surface.
- Advanced signal pulse. Consider a system consisting of a pulsed source, a detector at some distance, and a means to record the signal received by the detector as a function of time. The source emits a pulse, and after a time equal to the pulse transit period the detector receives the pulse. In addition, an advanced pulse would emanate from a distance and arrive at the source just as it was emitting, as in the case of the advanced ripples in the pond. This advanced pulse would pass the detector at one transit period before the source emitted the wave. The recorder would record the signals, one at a transit period after the source emitted the pulse, and one at a transit period before. Presumably the advanced wave forms from random background noise fluctuations. The pulse could be a light pulse from a laser source, a tick from an acoustic transducer, a water wave, or any other type of signal. Just as with the case of the converging ripples, the advanced pulse would represent a reduction in entropy from that of the random background fluctuations, and therefore could not form. In fact, this experiment has been carried out using microwave pulses (Partridge, 1973; Schmidt, 1980; Schmidt & Newman, 1980). The system was capable of measuring advanced pulses as small as $10^{-11.5}$ (10^{-8} for the earlier reference) of the power of the source pulses, but none were observed.
- Advanced observation of astronomical events. As in the case of the signal pulse, above, an astronomical event such as a solar prominence would be observable an equal amount of time after and before the event took place on the sun (Feinberg, 1975). This has not been reported.
- Retrograde macro-psychokinesis. Macro-psychokinesis, large psychokinesis effects often involving substantial expenditure of energy, are not necessarily in conflict with the second law of thermodynamics, as long as the instigating activity of the agent occurs concurrently with or in advance of the resulting effect on the receiver. Retrograde macro-psychokinesis with a reduction in the entropy of the receiver would not be allowed.

Documented cases of macro-psychokinesis do not fall into this disallowed category (Roll, 2003).

In summary, phenomena that would not be consistent with the second law of thermodynamics in forward-going time are those in which coherent signals emanate from background noise.

VIII. Discussion and Conclusions

Based on the bulk of the available experimental evidence, it appears that SI are consistent with the second law of thermodynamics and that the weak-violation hypothesis, described in the first paragraph of Section I, holds. Unless evidence to the contrary arises, SI experiments that have a chance to yield positive results are those in which the agent and the receiver each exhibit non-decreasing entropy.

The second law of thermodynamics may be applied not only to advanced SI, but also to SI in general because the results of a wide array of experiments give similar results independent of whether the agent providing the influence or the receiver of the influence acts first. These SI include precognition, remote perception, telepathy, and psychokinesis.

Activities of the agent and of the receiver in SI must each be consistent with the second law of thermodynamics independently because of the difficulty in distinguishing the agent from the receiver, as in trying to interpret whether a particular interaction is precognition or psychokinesis.

SI that are consistent with the second law of thermodynamics typically involve a quantum trigger with amplification. I divide examples into the following categories:

1. Human ↔ human. Examples involving living beings include precognition, prayer and healing, and telepathy.
2a. Human ↔ electronic random event generator. Examples include human-influenced random number generators experiments, precognition of computer-chosen images, and pre-recorded random clicks.
2b. Human ↔ non-electronic inanimate system. Some inanimate systems produce an outcome that may be influenced by SI, with a concomitant increase in entropy. These include a random mechanical cascades and the decay rate of pendulum oscillations.
3. Inanimate system ↔ inanimate system. Such a system is one in which there is an ostensibly random process in one system that may be influenced by the other. An example is the standard double-slit experiment in quantum mechanics in which a wave/particle may be influenced to sample two slits or pass through just one. This category is the one with the least experimental evidence for SI, and is in conflict with a commonly held belief that SI requires the consciousness of a living being.

The purposes of this paper have been to offer an approach to evaluating SI phenomena, and to aid in the design of further SI experiments. Although to date it appears that SI are consistent with non-decreasing entropy and with the second law of thermodynamics, we do not yet know for certain if these findings are indicative of a general principle.

Notes

[1] "Closed" means that the system does not interact with anything outside. In fact, no system is absolutely closed, and therefore in a practical situation one must determine whether the system may be approximated as being closed in that there is no significant effect by the outside on the entropy of the system.

[2] One may quibble that it is incorrect to use the word "never" here, as it is statistically possible that the entropy decreases spontaneously. However, for a system the size of a grain of sand or larger, it can be shown that the probability its entropy shows a significant spontaneous decrease is negligibly small over a time span greater than the life of the universe. That is a practical definition of "never."

[3] It may be asked whether the transfer of information involved in the SI is itself a significant entropy transfer. Without coherent triggering, such an information transfer does not involve significant entropy transfer. The amount of allowed information transfer may be quantified, and will be described in a future publication.

[4] Viewing this as advanced knowledge by the photon is attributing precognition to the photon. Alternatively, the same situation can be viewed as a case of telekinesis, in which the detection apparatus affects whether the photon is directed along both paths or just one when it is launched.

[5] Wheeler has stated explicitly that the observation of the light on Earth can be accomplished without human involvement, and therefore he prefers to call the process "registration" rather than "observation."

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