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Empirical Pictures of Time

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Abstract

Nothing has been more perplexing or controversial in the study of psi phenomena or in modern physics than the concept of Time. We discuss some aspects of current physics and of psi research that are particularly relevant to our understanding of Time and its meaning. Several unexpected experimental anomalies are presented that may give us clues about the nature of retrocausal influence. We show how some retrocausal effects and other anomalous phenomena might be explained without major injury to existing physical theory. A modified quantum formalism can give new insights into the nature of quantum measurement, randomness, entanglement, causality, and Time itself. The origin of Time and Clocks can be understood and developed from simple logical foundations. We also give some suggestions for future directions in experimentation, development of theory, and for involvement with the science community.

Empirical Pictures of Time[1]

It is probably fair to say that nothing has been more perplexing or controversial in the study of psi phenomena or in modern physics than the concept of *Time*. We have measured Time using the motions of the heavenly bodies, the changing of the seasons, the swinging of pendula, the beating of our hearts,... and today the oscillations of tiny particles to an accuracy of better than 1 second in 60 million years (NIST, n.d.). We often feel that Time is of supreme importance in our daily lives, and to prevent "wasting" it even wear a measuring device on our wrists. Yet no one seems to know exactly what Time is or what brings it about.

Time seems to "flow" only in one direction, and we use forward cause-and-effect reasoning pervasively, yet experiments sometimes seem to show influence and information moving backwards in Time. The fundamental laws of both classical and quantum physics are symmetrical in Time, yet we routinely expect our experiments to produce their results, not the other way around. To make matters worse, the concept of Time is seriously tangled and confused with those of causality, randomness, and even consciousness.

In this paper, we discuss the meaning of Time and its importance in physics and in psi research, some relevant experimental evidence, and an explanatory theory that does not seriously conflict with existing physics. We also attempt to untangle things a bit, and suggest a fundamental definition and origin for Time itself. Finally, we make some suggestions regarding future research directions.

Time in Physics

"To be perfectly honest, neither scientists nor philosophers really know what time is or why it exists." -- Paul Davies, physicist

Symmetry of Physical Laws

In general, the laws of physics, both classical and quantum, are invariant under time reversal. This means that the equations representing these processes are symmetrical in the time variable, and any solution for $+t$ is also a solution for $-t$.

Despite these strong time symmetries, we routinely assume only forward causality in much of our thinking about the real world, and in nearly all of the experimental sciences. Yet, despite our everyday experience, there is a considerable body of both anecdotal and scientific evidence suggesting retrocausal phenomena. Confusing matters further, the part of quantum theory that would prevent actualization of time symmetry and backward causal effects remains the most perplexing and poorly understood aspect of the theory, and is still enigmatic and contentious nearly a century after its initial discovery -- *measurement*. To better understand quantum measurement, and especially its relationship to Time, we must delve a little more deeply into the basics of quantum theory.

Asymmetry of Quantum Measurement

Quantum dynamics in the orthodox formalism includes two entirely different types of evolution or change -- *unitary evolution* described by the Schrödinger equation (linear, reversible, lossless), and *measurement* or projection (nonlinear, irreversible, information losing) by the Born Rule -- the notorious "collapse of the wavefunction" (Peres, 2003).

From a superposition of two states of a binary variable such as

$$\Psi = \frac{1}{\sqrt{2}}\left(|\mathbf{0}\rangle + |\mathbf{1}\rangle\right),$$

one alternative is selected (projected) during measurement according to the implied probability distribution (Figure 1). The outcome is traditionally assumed to be *entirely random*, causeless, and thus unpredictable. Only statistical statements can be made about the result, in this case a uniform distribution of **0** and **1** states. Once the measurement is complete, the resulting state has become a classical one, and subsequent measurements of the same variable will continue to give the same result. This scenario applies whether the situation involves the spin (up or down) of a particle, the path through a two-slit arrangement, or any other binary observable.

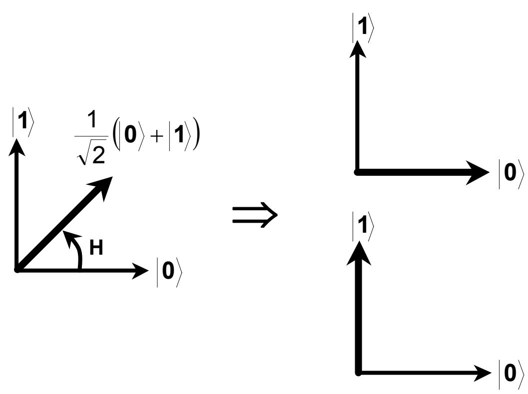

FIG. 1. Superposition and measurement as vectors in Hilbert space. A particle initially in state **0** is placed in superposition of **0** and **1** by a unitary transformation (rotation) H. Measurement, according to orthodox theory, projects the superposed state non-unitarily and unpredictably onto **0** or **1**.

This non-unitary collapse, or *decoherence*, of the wavefunction due to measurement has been the most vexing and controversial aspect of quantum theory from its inception, and yet it has been supported by many experimental tests to great precision. A wide variety of interpretations of the quantum formalism have been proposed to mitigate the practical and philosophical difficulties of this part of the theory, but none have met with complete acceptance. We give our own modified version of quantum theory below, and discuss its potential explanatory power.

The consequences of the assumed "collapse" are severe. We focus here on two of them: 1) the prevention of backwards or *retrocausal* influence due to non-linearity; and 2) the introduction of a fundamentally random element at the core of physical reality. By a "random" process or event, we mean one that is *uninfluenceable* (no inputs, no external affect possible) and *unpredictable* (no internal memory, no pattern possible). A random event is *isolated from the past*. While unitary evolutions are time-symmetric, and thus inherently permit reversed or backward influences to propagate, a lossy or random (causeless) event breaks the dependency connection (causal chain) and prevents backwards influence (Figure 2).

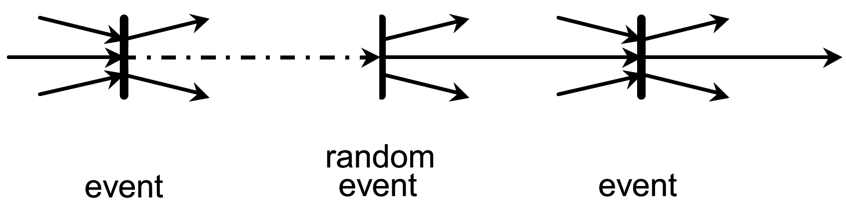

FIG. 2. A random event breaks the causal chain and prevents any possible backwards influence. Arrows represent influences (drawn conventionally forward) that connect a sequence of events.

According to prevailing quantum theory, measurement is thought of as a two-party interaction between a measuring apparatus and the system being measured. However, several researchers (Zurek, 1981; Zhang, Liu, and Sun, 2002; Cerf and Adami, 1996; Shoup, 2006) have postulated that quantum measurement should properly be considered as a *three*-way interaction among the measuree (the system of interest), the measurer (the experimental apparatus), and the environment (everything else), with each described as a fully general quantum object. A measurement really just entangles the measured system with the measuring apparatus and the rest of the environment, spreading prior entanglements around, a process known as *decoherence*. In this view, classical correlations and apparent randomness seem to appear in quantum measurement *only when the environment is ignored*. This is quite significant in that, *by this* *theory, measurement is entirely unitary*, reversible, lossless, and thus can allow backwards causal influence, at least in principle.

In orthodox theory, the result of a quantum measurement is random. But if a “random”, unknowable, non-deterministic choice did in fact occur in measurement, we would naturally ask where the information came from which determined this choice, and how did it enter the situation? Before the measurement, there are two possibilities extant, and afterwards one has been chosen and realized. Does a bit of information come from God himself for each “collapse” of a binary variable? This choice requires a bit of information, a reduction in entropy of the measured system. If, however, measurement is actually unitary, we can give up the assumption of fundamental randomness, and look for the source of the choice elsewhere, see below.

Entanglement

Quantum *entanglement*, a special state available only in the quantum realm, has often been suggested as a possible mechanism to explain anomalous phenomena such as telepathy and clairvoyance. In an EPR (Einstein, Podolsky, and Rosen, 1935) experiment, for example, two particles become entangled by an initial interaction, fly apart an arbitrarily large distance, each in its own superposed state, and yet when measured individually give highly correlated (but apparently random) results. John Bell (1964, 1978) showed that no local realistic theory can explain these correlations, and this result has been confirmed by many experiments.

It is now well accepted that entanglement *cannot* be used to transmit information, but can only impose a constraint of correlation. In psi research, correlation is sometimes enough to explain anomalous phenomena where several random or nearly-random data sequences are being compared (e.g. symbol guessing between a subject and a random target generator). But correlation alone may not be enough to explain other phenomena where real information transfer may be required (e.g. remote viewing of distant current events).

Entanglement is time insensitive in that either one of the entangled pair can be measured first, and the correlation will still be exhibited in comparison of the results. (In fact, by Special Relativity, it is possible for two observers to move so that each thinks they measured first.) Some theorists argue that EPR is best explained using a “zig-zag” of forward and backward Time (Costa de Beauregard, 2001), while others (Suarez, 2003) claim that quantum entanglement is best thought of as occurring outside of Time entirely. Still other physicists insist that Time is merely an illusion or a derivative of something more basic (Price, 1996; Barbour, 2001; Hellmann et al, 2007). Significantly, it has also been shown that *entanglement in the present can be created by means of an interaction in the future* (Elitzur, Dolev, and Zeilinger, 2002; Elitzur and Dolev, 2006). This latter possibility has important implications in psi research, as will be discussed in more detail below.

Time in Psi Phenomena

The notion of time has to be introduced if only to distinguish cause from effect:
Cause must always precede effect. -- Gerard ‘t Hooft, physicist, Nobel laureate 1999

There are two significant ways in which Time is relevant, even central, to the study of psi: 1) Some phenomena such as precognition directly contradict our usual notions of forward causality, and strongly suggest that information sometimes flows backwards in Time. A better understanding of Time is essential in explaining these effects. 2) Other phenomena such as present-time telepathy, while not directly evidencing backwards Time influence, may be better (only?) explained using a combination of backwards and forward influence. Both of these relevancies are explored further below.

Characteristics of Psi Phenomena

From the significant body of experimental evidence, a few striking and salient properties of these anomalous phenomena have emerged. We list a few of them for reference, but without thorough discussion, since the first has special significance for us here.

1. Time/order independence (clairvoyance vs. precognition)
2. Complexity independence (goal orientation)
3. Selectivity (resonance, “tuning in”)
4. Experimenter dependence (attitude, audience)
5. Small effects, difficult to replicate (at present, and perhaps fundamentally)

Perhaps the most shocking, problematic -- and thus the most profound -- characteristic of psi phenomena listed above is their *apparent independence of Time*, including especially precognition and even retroactive psychokinesis. In a common example, it does not seem to matter much whether a remote viewing takes place before, during, or after the viewed event (Radin, 1997; Targ and Katra, 1999; Braud, 2003). Persistent evidence suggests strongly that thinking about these phenomena in terms of the usual notions of cause and effect is likely to be counterproductive -- and may in fact be *the* major impediment to a deeper understanding.

Evidence of anomalous correlations (which are in principle timeless), as well as retrocausal effects that apparently involve information transfer, are relatively common in the literature. Schmidt (1976, 1987, 1993) conducted innovative experiments that appeared to show retrocausal effects, including retroactive PK on pre-recorded targets. Radin (1997a, b) and

Bierman and Radin (1998) have shown presentiment effects repeatedly in experiments involving measures of autonomic response.

Many specific experiments in the literature have been designed to elicit and to test retrocausal effects, but for further hints about an explanatory mechanism, we now look at two examples of retrocausal effects that are not typical, nor even intentional.

Unintentional Backwards Influence on Random Processes

A network of random number generators (RNGs) has been developed by the well-known Global Consciousness Project (GCP), and has been in continuous operation since 1998. Approximately 70 generators exist today scattered around the globe, each sending 200 random bits per second back to a central server for storage and later analysis. Details, analysis methods, and all generator data are available on the GCP website (Nelson, n.d.). According to the GCP, behavior of the network sometimes deviates significantly from chance, especially around times of notable human events.

In particular, highly unusual behavior was seen in the network on and around the tragic day of September 11, 2001. This behavior has been discussed in detail elsewhere (Nelson, 2002; Nelson and Bancel, 2006), so we present here only one less-publicized view of the data.

On and around 9/11, over 30 random generators ("EGGs") were operational and functioning normally.[2] Figure 3 shows the standard cumulative χ^2 statistic for several groupings of 32 generators for the full day. Data have been aligned (pinned to zero) at 0600 hours (this begins a period of relative quiescence for all four curves and significantly precedes the key events of the day), and filtered with a one-hour sliding window.

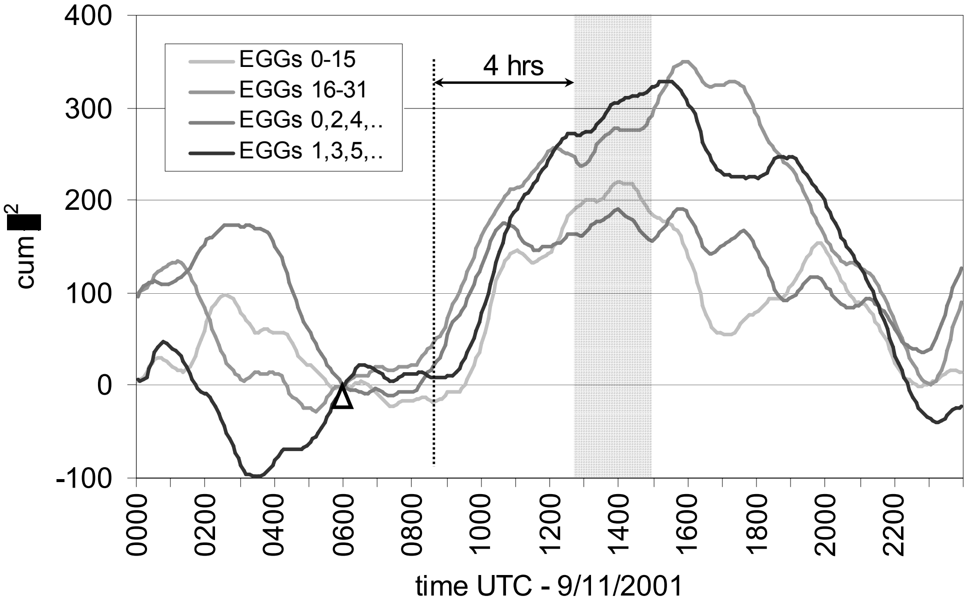

FIG. 3. Correlations among 32 random generators (EGGs) on September 11, 2001, combined in four groupings of 16 each for comparison. Deviations beginning 4 hours prior to the principal events (gray area) of that day suggest retrocausal influence, and thus no prosaic explanation. Curves are pinned to zero at 0600, a common quiescent point.

As can readily be seen, beginning approximately four hours before the events, variance of the generators dramatically increased. Four different groupings are shown to emphasize that significant deviations were seen simultaneously across most if not all the generators, not just one or a few. The disturbance continued for more than 12 hours, gradually subsiding later in the day similarly among the groupings. No deviation of this magnitude has been seen anywhere in the entire database collected from the GCP generator network. Note that the four-hour prior response rules out any of the usual prosaic explanations such as electromagnetic or other known effects on the generators or the data due to unusual human activity following the tragic events of that day.

It is difficult to interpret such behavior in many supposedly random devices, but evidence has been amassed by the GCP project from this event and many others for correlations with global human concerns (Nelson, Radin, Shoup, and Bancel, 2002). For our purpose here, we simply emphasize that 1) these random devices deviated significantly from expected chance behavior during the events of 9/11, and 2) that the deviations began well prior to the events with which they were presumably associated[3]. We take this behavior as (anecdotal, not formal) evidence of *mutability in supposedly random uninfluenceable processes*, and of *retrocausal influence* upon them, *without any direct intentionality* or focus on the generators by any humans (except perhaps the project researchers and observers after the fact).

Were the generators somehow altered by the events or the outpouring of attention and emotion on that day, or were they influenced by a retroactive experimenter-mediated effect, or something else? Since there is no evidence or known mechanism whereby this attention and emotion could have *directly* affected the RNGs, it seems that the only remaining plausible path for this influence to have taken was through the one place where the data are collected together and any deviations become apparent -- the collation and analysis of the independent data streams by the experimenters -- and then backwards to the data generators themselves.

Unintentional Backwards Influence on Subjects

Another unexpected precognitive effect related to 9/11 was seen in a completely separate dataset. On our public "GotPsi?" experimental web site (Shoup and Radin, n.d.), a simple 5-choice card guessing experiment has been running since August 2000. As of August 2008 over 30 million trials have been recorded, and the site is currently logging N = 15-20,000 trials per day from users all over the globe. Details of the "Card Test" and several other experiments on the web site along with some preliminary results can be found in an early report by Radin (2002).

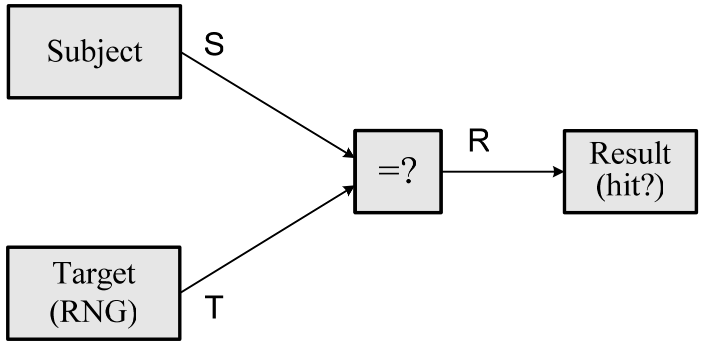

FIG. 4. A simple forced-choice card-guessing experiment.

In the on-line Card Test, shown schematically in Figure 4 and pictorially in Figure 5, the subject is asked to guess which of five displayed playing cards has a picture "on the other side" by clicking on that card. His guess (S=1..5) is compared with the target card (T=1..5) and the result is either a hit (R=1) or a miss (R=0). The result of each trial is shown to the user, and runs of 5, 10, 25, or 100 trials are tallied and the odds against chance displayed.

FIG. 5. One completed trial in the on-line Card Test.

Figure 6 below shows the daily hit rate for all subjects (typically 100-200 users each day) over two years of operation of this experiment, March 2001 to March 2003, filtered with a sliding average window of 30 days, and normalized as $z = (n_{hit} - n_{exp})/(\sqrt{N}*0.4)$.

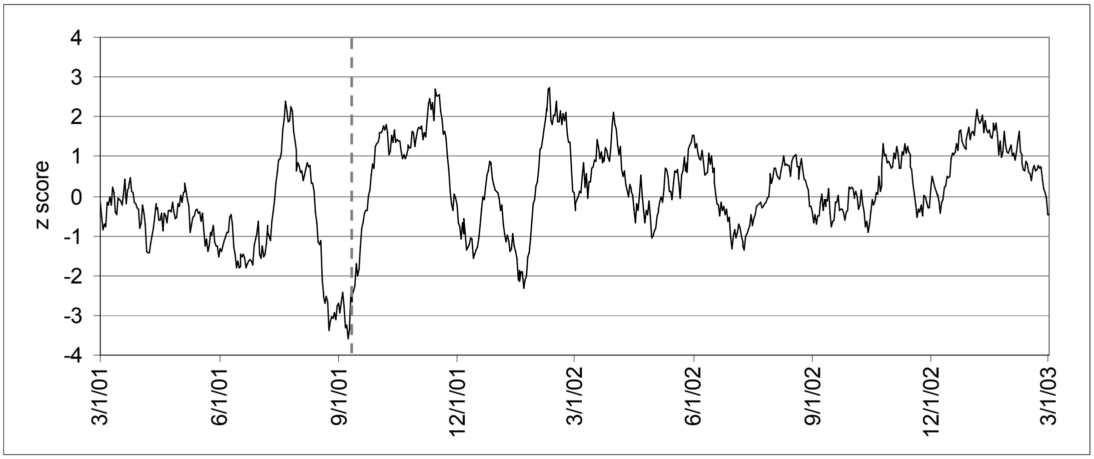

FIG. 6. Card Test normalized daily hit rate for all subjects from March 2001 to March 2003, 30-day trailing average. The dashed line indicates September 11, 2001, and the center of a highly unusual period of scoring.

The daily hit rate appears to behave statistically as the expected random walk except perhaps for the striking peak and deep notch in July through October of 2001. For unknown reasons, the hit rate rose well above $z = 2$ (max $z = 2.4$, $p = 0.0082$) and then fell dramatically during the period just prior to September 11, 2001, staying below $z = -3$ (min $z = -3.6$, $p = 0.00016$) for over two weeks.[4] (This almost continuous drop of nearly 6 standard deviations is itself highly unlikely, of course, no less given its timing.) Then almost immediately after 9/11, the hit rate rose steeply again, and returned to ostensibly random behavior, which continues to this day. Nowhere else in the entire database of the Card Test is any similar excursion found.

Although all of this behavior could be purely due to chance, it seems that that two weeks before 9/11, subjects participating in the Card Test suddenly became quite poor at guessing cards, selecting incorrect cards far more often than chance would predict. Remarkably, almost immediately following the key date of 9/11, performance vastly improved for a time, and then returned to varying randomly in seeming accordance with expected probabilities. If it is assumed that results during this highly unusual period are somehow related to the tragic events of

September 11, 2001, then they are precognitive by several weeks, and constitute evidence for retrocausal influence on this experimental task completely unintended by anyone.

Unlike the GCP random generators, the target distributions in the Card Test during this period show no significant departure from chance expectations. This does *not* necessarily mean that the (single) RNG in this case was not perturbed, but only that the resulting target distribution continues to appear random. So another hypothesis must be that the generator and the subject were somehow anti-correlated during this period, each still appearing approximately random by itself. Note that we cannot in principle distinguish psi missing (where information from the target is somehow available to the subject, and is used to miss) from PK on the generator unless the subject's guesses are significantly non-randomly distributed (Shoup, 2002).

Both significant extra-chance hitting and missing constitute evidence for non-zero correlation between subject and target, and thus some coordinating influence must have been acting between them. Since there is no known channel connecting subject and target generator directly, and no plausible common influence in the past, it is again suggested that this anomalous correlation is mediated by the only remaining path available -- their interaction in the future result comparison and analysis, as discussed below. This interaction could presumably produce such correlations whether S is chosen prior to or after T, and we separate these two cases below to look for any difference.

Evidence of Time/Order Independence - Offset Targets

Looking more deeply into the previous example, it is the case that target generation in the Card Test is actually done in a way that allows further testing of the hypothesis of the Time independence of these anomalous effects. Unknown to the subject, several different means of target generation are employed in the Card Test on a trial-by-trial basis, as depicted in Figure 7.

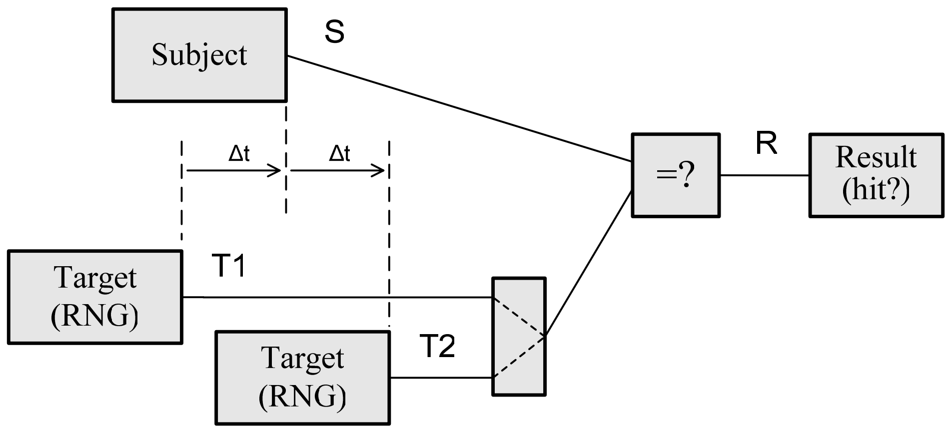

FIG. 7. Card Test experiment with target card T1 chosen before, and T2 after, the subject's guess.

For each trial, *two* target cards are potentially generated, one prior to the subject's guess (T1), and one following (T2). An additional random choice determines which of the two targets will be selected and used to compare with the subject's guess. Figure 8 shows the daily hit rates separately for those trials using the T1 targets and those using the T2 targets.

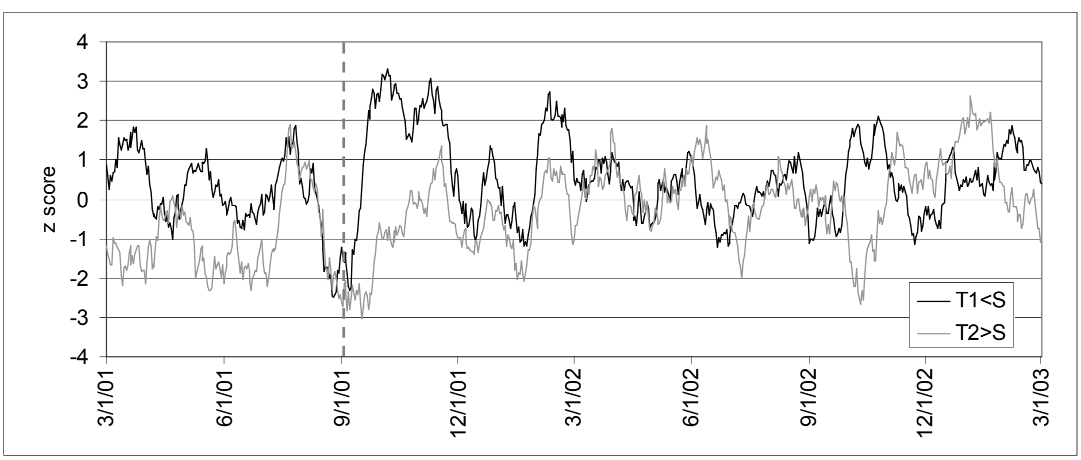

FIG. 8. Normalized Card Test hit rate for trials with targets T1 (generated before the subject's guess) and T2 (afterwards). Note the unusual behavior of the two curves surrounding 9/11/2001 (dashed line) and thru 2002.

As with the combined daily hit rate shown previously, each of these curves represents the success rate for the subject's guess matching a randomly generated target. By the null hypothesis (chance behavior), these curves should represent two *independent* random walks. Contrary to the expected behavior, however, beginning in July 2001 the two hit rates behave remarkably similarly and apparently non-randomly for most of an entire year. They rise together to a peak near z = 2 in mid-July, then fall closely together to a low below z = -3 through the beginning of September. Then shortly after 9/11, the T1 (prior) hit rate rises dramatically while the T2 (post) hit rate remains low for several more weeks, and rises more gradually. The curves appear to rejoin in November, track each other closely again throughout the first six months of 2002, and then begin to diverge and revert to the expected independent random walks (which continue to the present day). Figure 9 shows this correlation between the T1 and T2 z scores computed as a Pearson r. Note the anomalous high correlation (over 0.9) periods for several months both before and after 9/11.

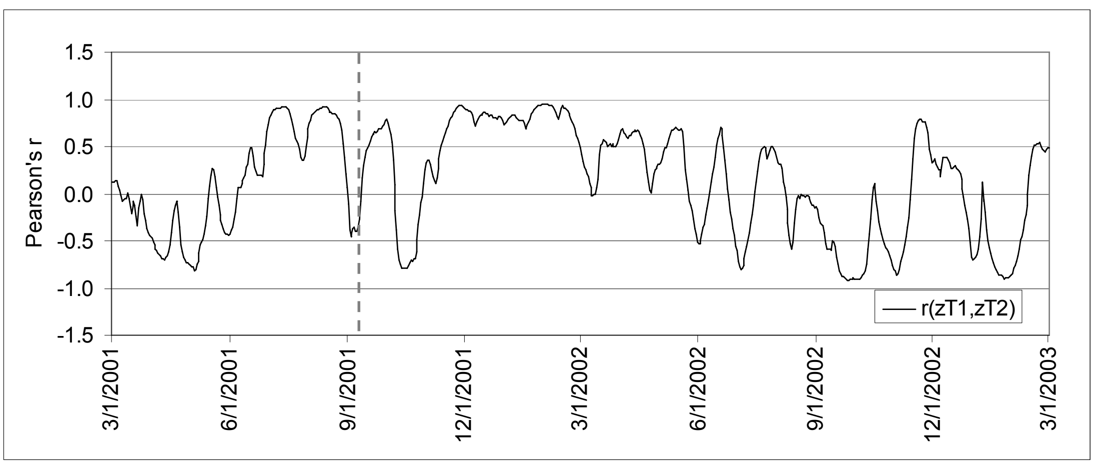

FIG. 9. Correlation between the T1 and T2 z scores as a Pearson's r with 30-day sliding window.

Anomalous correlations are apparent between the T1 and T2 hit rates, and show variation relating to the special date of September 11, 2001. During a one-year period surrounding this date, the hit rates for prior and post targets behaved remarkably similarly and anomalously, suggesting that a common influence was affecting performance in both conditions, with a time constant measured in weeks -- yet the subjects were only intending to guess correct cards throughout. But interestingly, there is also a clear (but temporary) distinction between the two conditions for a period of about two months just after 9/11, suggesting that the time offset was somehow discernible to the subjects or affecting the targets during this period.

The data from these two experiments is tantalizing, not only for the precursory effects, but also the long-term effects reminiscent of those seen in the GCP data analyses (Nelson, n.d.). Further study is certainly indicated. We can only hope that with improved analysis techniques, calamities of the magnitude of September 11, 2001 will not be necessary to test new hypotheses.

Can Physical Theory and Psi be Reconciled?

"For us believing physicists, the distinction between past, present and future is only an illusion, even if a stubborn one." -- Albert Einstein, physicist, Nobel laureate 1921

Most physicists still assume -- largely without examination -- that psi phenomena cannot be taken seriously because they *appear* to violate well-confirmed and accepted physical laws, and especially offend our notion (assumption) about forward cause and effect. In particular, precognition would seem to require information transfer from the future, supposedly a logical impossibility. In fact, it has been asserted by many scientists that a *complete rewrite* of physics would be necessary if these phenomena are real (e.g. Gell-Mann, 1994; Kaku, 2008a, b). But as we suggest below, this is simply not so, and only modest changes in the foundations of quantum theory are needed to allow and to explain many of the psi phenomena that have been observed consistently in laboratory experiments as well as anecdotally for many years (Broughton, 1992; Radin, 1997; Broderick, 2007).

Some theories that have been created to deal with the stranger aspects of quantum phenomena could perhaps permit psi as well. Transactional interpretations of quantum mechanics, the possibility of entanglement due to future interactions, the idea of unitary measurement, all mentioned above, contain aspects of both forward and backward interaction. Observational theories of psi by Houtkooper (2002, 2006) and others argue that the outcome of a measurement remains indeterminate until later constrained by a comparison with another quantity. As also mentioned above, a proper understanding of Time may be needed not only to explain precognition, but also to explain other phenomena that do not appear at first to require any backwards influence. With particular reference to the present subject of retrocausation, the volume of papers produced from the 2006 AAAS conference "Frontiers of Time: Retrocausality - Experiment and Theory" contains many relevant contributions. (See references.)

Analysis of a Simple Experiment Involving Anomalous Correlations

Let us return to the simple guessing game in canonical form given above in Figure 2, but now considered in the abstract. Typically, the subject tries to make his guess (symbol S) match a target generator (symbol T), and an equality test produces result (R) indicating success (1, a hit, or 0, a miss).

Suppose an experiment of this type has been conducted, and the results show a hit rate higher than that expected by chance. We assume that all forms of ordinary signaling or leakage between subject and the target generator have been prevented, and ask how this physical anomaly could be explained. Consider four possible paths by which information or influence could have traveled to bring about this result, as highlighted in Figure 10.

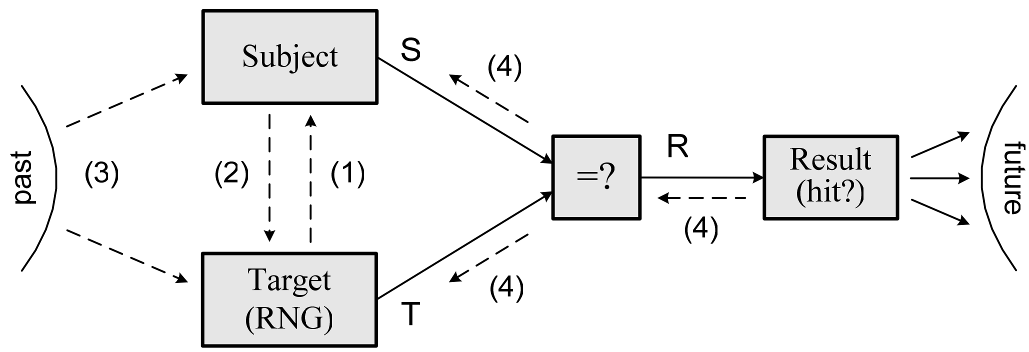

FIG. 10. A simple forced-choice experiment, with four possible paths of influence (dashed) by which an anomalous correlation between Subject and Target could have been brought about.

1. Influence directly from T to S. The subject was somehow able to sense the target symbol directly and adjust his guesses accordingly. This was at one time a typical explanation involving clairvoyance (S chosen after T) or precognition (S chosen before T). The associated mechanism would have to include a previously undetected means of information transfer such as a new force or field, and an unappreciated human sensitivity or sense organ. This hypothesis seems highly unlikely, especially since there may be many target generators in the world from which to select. Moreover, if the target is chosen after the guess, then the subject must possess some precognitive ability, and this would require information flow backwards in Time, contrary to the "law" of cause and effect.

2. Influence directly from S to T. The subject was somehow able to affect the target generator directly. This is the usual psychokinetic explanation, again difficult to mechanize, yet apparently consistent with many careful real-world experiments (Jahn and Dunne, 1997; Schmidt, 1993). Quantum processes in the RNG that are now considered to be fundamentally random would have to be influenceable, and information conveyed in some currently unknown way. Again a new or unnoticed force or field would seem to be necessary -- unlikely in the face of existing and well-tested physical theory -- along with the selection problem as above.

3. Correlations due to past interactions. The subject was somehow able to make use of correlations or entanglement between himself and the target generator due to interactions in the past. Or perhaps the subject somehow knows something about likely target sequences due to past common origins. After all, real RNGs have a physical history, and their performance may not be entirely isolated from the past, as is usually assumed. According to current cosmological theory, all matter has interacted in the past, even if quite remotely. It is generally assumed that any residual correlations that existed between well-separated objects has long ago been erased by unavoidable decoherence and particle interactions at historical temperatures, but this seems far from conclusively established. Again we have the selection problem, since there may be many such generators. And while this hypothesis might explain clairvoyant or precognitive effects, some way to *affect* the target generator would still be required in order to explain psychokinesis implied by any deviations from randomness seen in the target sequence.

4. Correlations due to future interactions. The subject was somehow able to make use of correlations or entanglement between himself and the target generator due to interactions in the *future*. It might be that the presence of anomalous results in the future exerted influence backwards through the equality constraint to bring about such correlations, with S influencing T or vice versa or both. Or perhaps the subject and target streams became entangled via their interaction at the equality test, while both streams remained independently random.

It is hypothesis 4 in which we are most interested. For hypotheses 1 and 2, an additional unknown path of influence or information flow would be necessary between S and T, and this seems to be in serious conflict with well-established physical theory as well as experimental data. However, alternatives 3 and 4 may not require any direct or indirect information transfer between S and T, instead relying on correlation alone, and thus do not imply such a mysterious path or the difficulties associated it.

In addition to providing the necessary property of Time independence, hypothesis 4 (correlation due to future interactions) can arguably account for many if not all of the so-called telepathic, clairvoyant, precognitive, and psychokinetic anomalistic effects apparently exhibited in such experiments.[5] It provides good agreement with the characteristics of psi listed above as well, without requiring new paths or mechanism or any major insult to well-accepted physical law -- *if* we allow symmetrical (bi-directional) causal influence as argued above.

From this theoretical viewpoint, there is no essential difference between precognition (a future event affecting the past) and retro-PK (the same). We emphasize that the latter does *not* imply *changing* any previously recorded data (Schmidt, 1976), but retrocausally influencing how it was generated "in the first place". This is the essence of Time independence or backwards-in-time influence. (Compare with the Transactional Interpretation of quantum mechanics (Cramer, 1986, 2006), and Decision Augmentation Theory (May et al, 1995).)

Order Independence and Quantum Nonlocality

There is a non-obvious connection between the Time independence shown in the simple abstract experiment above and the Time independence associated with quantum entanglement and measurement. With a simple rotation, the experimental diagram above gives something quite suggestive of an EPR configuration, see Figure 11 below. If we constrain the Result stream to be all 1s (hits), then the S and T streams must be perfectly correlated (identical), just as in the case of the spins of an entangled EPR particle pair measured at the same angle.

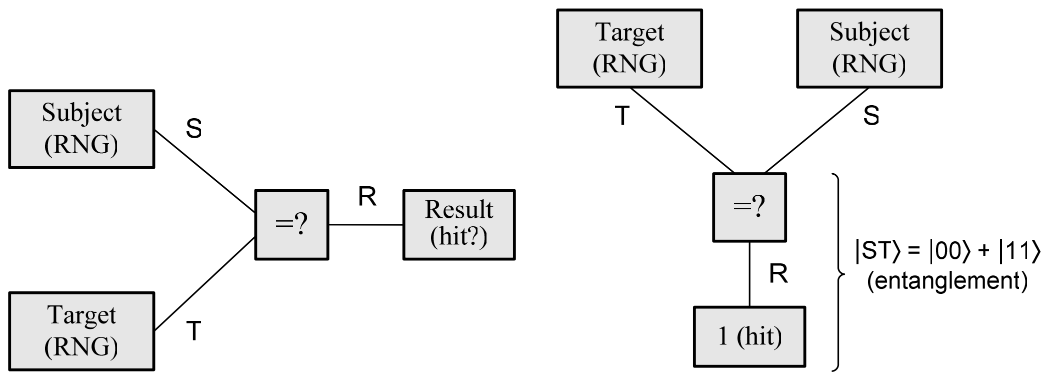

Figure 11. Rotation of the simple psi experiment suggests an EPR configuration.

In the usual EPR arrangement, this constraint on the "Result" would be considered as a *preparation*, since it creates the entanglement, and occurs prior to measurement of the S and T spins. But the real point here is that the entire situation *in either rotation* can be viewed in terms of timeless bidirectional relations, and the order of the S and T measurements is not relevant to their correlation. Because of the equality constraint, the S and T streams are jointly constrained no matter what their time sequence. With respect to the simple guessing experiment above, the usual EPR arrangement is just a special case, namely complete entanglement at the "source" (R) followed by identical measurements at S and T, in either order.[6] (In this analogy, we are assuming the subject to act essentially as an RNG too, producing an approximately random distribution of guesses.)

Randomness and Causality

A quantum-random process or device is considered to be completely uninfluenceable and unpredictable, a box with no inputs, producing only an output stream. In view of the preceding discussions, where we theorize that all interactions are bidirectional and relational, causal influence can be thought of as flowing backwards in Time as well as forwards. In this view, an RNG is not solely an output device, but can be affected backwards in Time from observations and other events to which it is connected. By this theory, the *output* of a truly random source is actually more like an *input*, and its internal mechanism is vacuous or merely cooperating.

We conjecture that the output of a real-world quantum RNG usually appears to be totally random because in typical situations it is connected to macroscopic devices operating at room temperatures, and the apparent randomness is a reflection of the highly disorganized microstate of the observing device(s). We know from experiments that indeed such a device *can* be influenced, and by far the most parsimonious explanation seems to be that the device is being manipulated via its output. Thus to understand deviations from randomness observed in an RNG, we should look to retrocausal influences from the measuring processes and the observers.

What is Time, and What is a Clock?

Time is nature's way of keeping everything from happening at once. Space is what prevents everything from happening to me. -- (attributed to) John Archibald Wheeler, physicist

We return then to the central question of the nature of Time. Fundamentally, *Time is an indicator of change*. Time "passes" when something changes, or to be more specific, when the value of a variable is different from its "previous" value. The previous value must be something we have remembered, i.e. stored in a "memory" or delayed from the "current" value. So, in looking for change in some variable, and thus the passage of Time, we constantly compare the value of the variable to its value remembered, or "last time", see Figure 12.

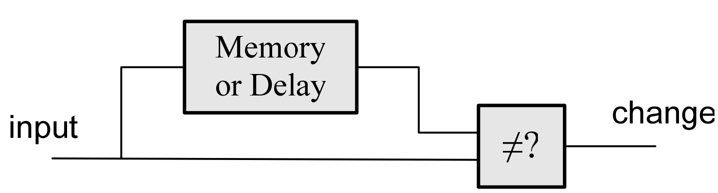

FIG. 12. A change detector compares its input value with the previous stored value. When the values become unequal, Time has "passed", as with a single tick of a clock.

The *memory* element needed here may be created in abstract terms by a self-confirming (looped) logic expression such as **X = X**, or, using complement (inversion, logical NOT) as the simplest basic logical operation, **X = ~~X**. Interestingly, the similar but paradoxical self-denying logic expression **X = ~X** creates a *clock*, an oscillator. Figure 13 shows two simple logical circuits with feedback that implement a memory and a clock, the most fundamental and essential time-related elements of any computer.

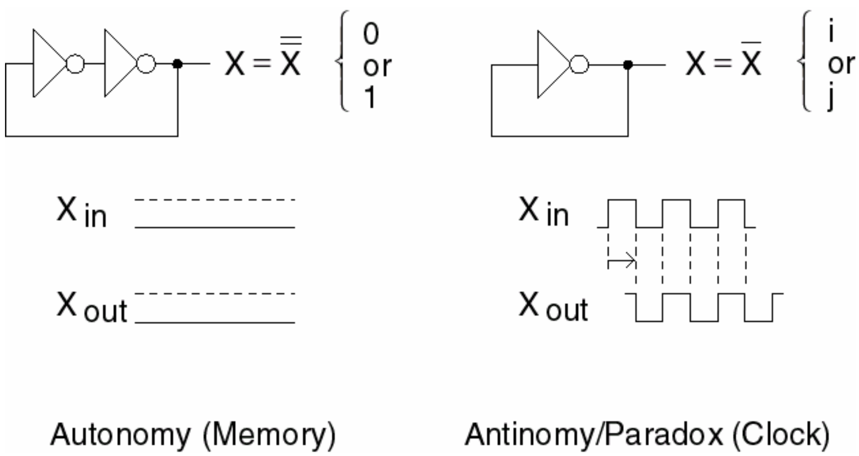

FIG. 13. Memory and Clock as simple logic circuits. The triangular elements represent inversion, or logical NOT.

The memory element merely retains its current value indefinitely, never changing, while the clock (oscillator) is a source of constant change, its logical values akin to the tick-tock of a mechanical clock. By counting these changes, we can determine a discrete time interval or "length" of time, just as a conventional watch or clock does, whether mechanical or electronic.

These simple abstract models are suggested as an indication of the ultimate origin of Time, and how it can be generated and understood at the deepest level. Further exploration of the subject of Time at this level is unfortunately beyond the scope of the present paper. See Shoup (1993, 1995) for more about abstract logic circuits and their relation to physics, and Shoup

(2008) for further discussion of discrete time, clocks, motion, and relativistic velocities derived from notions of primitive “pre-space” and “pre-time”.

Next Steps - Experiment, Theory, and Acceptance

"The way to do research is to attack the facts at the point of greatest astonishment." -- Celia Green, philosopher, psychologist

Toward New and Illuminating Experiments

Allowing for the possibility of retrocausal influence, the potential exists for some new directions in experimentation, with emphasis on Time and related physical variables. Suggested:

1. Further analyze already-conducted experiments (especially large ones such as the GCP network and GotPsi) for retrocausal effects on RNGs and on subjects. These could include investigating probable vs. actual futures, propagation of influence in Markov chains, and backward information transfer, even if unintentional. Use factoring in large datasets to look for experimenter-related effects.
2. Search for and analyze other experiments already conducted, preferably by other scientists in other fields, looking for presentiment and other possible backward effects in their experimental data.
3. Create a new much larger RNG network using easily-downloadable software (timing- or noise-based randomness). Search for deviations in other supposedly random databases such as lotteries, astronomy (SETI?), particle physics, etc.
4. Tease apart more of the already known physical variables such as local sidereal time, lunar phase, and local geomagnetic parameters in both new and past data.
5. Design and conduct experiments to carefully manipulate the size and complexity of observers and future dependencies to a stream of random events. Look for

related effects backwards on the generators. Focus multiple subjects on a single RNG stream and look for interference effects. Implement a closed loop (bilking) arrangement conditioned on a trial-by-trial basis.

Toward New and Deeper Theory

A timeless, relational outlook brings the opportunity for new theoretical explorations from which experimental tests may be derived. Suggested:

1. Further explore measurement as a unitary 3-way interaction, clarifying for wider acceptance, and looking for additional testable predictions. Take inspiration and experimental ideas from the delayed choice and quantum eraser experiments.
2. Explore the further implications of backwards-in-time influence including a model of sequential processes in a Markov chain, for example.
3. Explore further consequences of retrocausal influence on random processes, predicting behaviors of different RNG types, configurations, recordings, etc.

Toward Acceptance and Mainstream Participation

The current circumstances with regard to acceptance of psi phenomena and psi research in mainstream science might be likened to a "perfect storm". Consider:

1. *The phenomena are small, elusive, difficult to replicate, and seem to depend upon various poorly understood or ephemeral variables including even the attitude of the experimenter.* Experimental designs and technique will continue to improve, but a theoretical breakthrough is necessary to overcome the real problem here.
2. *The phenomena appear to violate well-established physical laws.* They don't, but physical theory must be modified somewhat, and a different viewpoint taken in order to allow the jettisoning of past incorrect assumptions. See above.

3. *The "noise level" in the area is quite high*, perhaps greater than in any other area of human experience, with many odd phenomena being claimed by wishful or incautious thinkers (or worse), and with proposed explanations that defy common sense as well as science. Unfortunately, the fear of "guilt by association" is high among most scientists today, and this high noise level dampens interest. In decades long past, study of anomalies may have been considered a sign of progress seeking and scientific courage, but academic and funding agency politics make this more difficult and rarer today.
4. *The phenomena are claimed and investigated mostly in the realm of psychology*, and tentative explanations often involve vague or poorly understood concepts such as "consciousness", "intention", and "mind". This is a serious continuing problem for the field of research called "*para*psychology" (outside of or beyond psychology, which itself does not often receive the appropriate respect from the "hard" sciences), the study of the "*para*normal" (not normal, whatever that is), and possibly invoking explanations in "*para*physics" (outside or beyond existing physics). In the author's opinion, all such nomenclature is a significant barrier to acceptance by and involvement with mainstream science, the Parapsychological Association's long membership in the AAAS notwithstanding.

However, if psi phenomena were to become accepted and widely studied in mainstream science, the outcome could be very positive. Consider:

1. The significance to many fields of science, especially physics and cosmology, would be very great indeed. The scientific method itself would be rethought.

2. The significance to society would also be large in terms of a new viewpoint on reality, causality, Time, and ultimately ourselves. The philosophical effects of such a change in science would subtly but profoundly permeate culture, similarly to the revolutions associated with relativity, quantum physics, and evolution.
3. These changes in science would at long last bring about a substantial, meaningful bridge between Eastern and Western thought and culture. Over time, the two apparently conflicting, but actually complementary, ways of looking at the world would become unified, and could contribute to greater harmony world-wide.

Summary and Concluding Remarks

We have tried to show how the concept of Time appears, and the role it plays, sometimes directly, sometimes subtly, in modern physics. Our current understanding of Time surely is inadequate, challenged by recent developments in particle physics and cosmology, by quantum phenomena, and perhaps most of all by apparently retrocausal phenomena such as precognition. The two experiments discussed above show that backwards influence can have unconventional and important effects in experiments even if they are not based on intention in the usual manner, and can yield important clues about psi functioning.

Our understanding of the nature and the experience of psi phenomena are deeply intertwined with our technological culture and its worldview. The habit of cause-and-effect thinking and the everyday experience of the one-way "flow" of Time still dominate. But, as we have tried to show, by altering our notion of causality and taking full account of both forward and backward influence, many of these seeming mysteries will become understandable.

The theory we have presented in summary is as follows:

1. Quantum measurement, when properly viewed, is unitary, lossless, reversible, and thus in principle permits propagation of retrocausal (backwards in time) influence. Measurement is exactly symmetrical with preparation, and there is no “collapse”.
2. Quantum measurement does not give a random result, and its apparent randomness comes from backwards influence of future observers and the environment. There is no fundamental randomness at the core of physics.
3. All interactions are therefore bidirectional and relational. Cause-and-effect is an assumption that should be applied symmetrically in Time, or discarded.

A further reconsideration of these matters leads us to a deeper understanding of Time:

1. Time is discrete, and “passes” whenever a variable changes.
2. A clock is created from a self-referring (oscillating) logical device.
3. A Time interval is defined by counting the ticks of a clock.

With the stakes as high as causality, randomness, and Time itself, it is difficult to overstate the importance of research into psi phenomena and the related physics necessary to understand it. To this end, we need to foster greater acceptance and involvement with mainstream science by 1) exceptionally careful experimentation and reporting of results; 2) better theorizing that recognizes and meshes with existing physics; 3) focusing on simple core phenomena over the stranger, more difficult to investigate; and 4) recognizing the importance to skeptical scientists in other fields of careful naming, descriptions, claims, and speculations.

Our goal in this research should be to build a better bridge between science and the entire human experience, and thus to expand the reach and the intellectual power of science, and thus to bring about a better partnership with the whole of nature.

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[1] Two meanings of the word "empirical" are intended by the title: 1) "Derived from observation or experiment", that is, suggested or observed in experiments in the real world; 2) "Capable of being verified or disproved by observation or experiment", i.e., suggested by theory and testable in the real world. Both meanings have relevance here, as they encompass the complementary activities of derivation of theoretical hypotheses, and testing them via experiment. The word "time" is capitalized frequently to emphasize it as a special concept.

[2] Note that no disruption of data collection was observed during or around that day, and no data was lost or compromised due to the social upheaval that took place following these events.

[3] May and Spottiswoode (2001) have claimed that the generators behaved normally on this day, but if the report is read carefully, it actually gives strong evidence for the reality of the effect! See especially Figure 10.

[4] These curves are the result of a trailing average filter, so each point sums data from the entire previous month. Bearing in mind this caveat, the behavior of the data and the sharp movements in the curve are striking.

[5] We hope the reader will agree that the standard terminology of telepathy, clairvoyance, precognition, and psychokinesis is antiquated, misleading, and in reality an impediment to progress. These phenomena are not separable, and by all indications are very likely to be explained by variations of the same physical mechanism.

[6] While the similarity here is not trivial, we hasten to add that this simple binary configuration does not capture the full generality of the non-local phenomena demonstrated in EPR arrangements and relevant to Bell's Theorem, notably in rotations of the measuring angles.