

Correlations of Random Binary Sequences With Pre-Stated Operator Intention: A Review of a 12-Year Program

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Abstract — Strong correlations between output distribution means of a variety of random binary processes and pre-stated intentions of some 100 individual human operators have been established over a 12-year experimental program. More than 1000 experimental series, employing four different categories of random devices and several distinctive protocols, show comparable magnitudes of anomalous mean shifts from chance expectation, with similar distribution structures. Although the absolute effect sizes are quite small, of the order of 10^{-4} bits deviation per bit processed, over the huge databases accumulated, the composite effect exceeds 70 ($p \approx 3.5 \times 10^{-13}$). These data display significant disparities between female and male operator performances, and consistent serial position effects in individual and collective results. Data generated by operators far removed from the machines and exerting their efforts at times other than those of machine operation show similar effect sizes and structural details to those of the local, on-time experiments. Most other secondary parameters tested are found to have little effect on the scale and character of the results, with one important exception: studies performed using fully deterministic pseudorandom sources, either hard-wired or algorithmic, yield null overall mean shifts, and display no other anomalous features.

Keywords: consciousness — anomalies — human/machine interaction — random event generators

I. Background

The role of human consciousness in the establishment of physical reality has been debated in many contexts and formats throughout every era of scientific history. The issue was central to ancient Egyptian and Greek philosophy, and to the enduring Hermetic tradition from which classical empirical science emerged. Even well into the period of scientific enlightenment, scholars of the stature of Francis Bacon [1], Robert Hooke [2], Robert Boyle [3], and Isaac Newton [4] addressed many of their empirical investigations to "the mystery by which mind could control matter" [5]. Although the maturing scientific establishment of the following two centuries came largely to dismiss such possibility, a number of distinguished physicists, including J. J. Thompson, William Crookes, Lord Rayleigh, and Marie and Pierre Curie continued to regard this topic as relevant to their scholarship, and were active participants in the Society for Psychical Research [6]. A subtler form of the question arose in the early "observational" interpretations of quantum mechanics

which were construed by a number of the patriarchs of modern physics, including Planck [7], Bohr [8], Schrödinger [9], de Broglie [10], Heisenberg [11], Pauli [12], Einstein [13], Jeans [14], Eddington [15], Wigner [16], Jordan [17], and von Weisacker [18], to raise important questions of the implicit or explicit role of human consciousness in the collapse of the wave function. Although they vigorously debated such possibilities from both scientific and philosophical perspectives, little consensus was reached, other than the need for better direct experimental data.

The enigma of consciousness continues to interest some contemporary physicists in such contexts as the non-locality/EPR paradox/Bell's theorem debates [19], single photon interference [20], causality violations in thermodynamics [21], neurophysics [22], complexity and chaos theory [23], and numerous other aspects of quantum epistemology and measurement [24, 25], once again without much resolution. Indeed, although a myriad of theoretical and empirical attempts have been made to define the elusive concept of consciousness itself, curiously little agreement on its origins, substance, characteristics, or functions has yet been achieved. Some of these efforts relegate consciousness to a complex of emergent phenomena of the human brain, and thus to an ensemble of neurochemical and neuroelectrical processes [26, 27]. Others attempt to invoke quantum indeterminacy in explication of brain function [28]. While many philosophers of science maintain that the concept of consciousness is so intrinsically subjective that it must be excluded from scientific attention, others plead that scientific scholarship cannot indefinitely ignore such dimensions [29].

Earlier in this century, attempts to codify the psychological dimensions of the problem were undertaken by a community of "parapsychologists" rooted in the pioneering research of J. B. and Louisa Rhine [30]. In most such studies, the consciousness aspect hypothesized to correlate with the behavior of physical systems entailed some form of volition, intention, or desire, a presumption consistent with the premises of most religions, mystical traditions, personal superstitious practices, and the innate human propensity to hope or to wish. Portions of this early work attracted the attention of Pauli [31] and other quantum physicists. Einstein reports on a conversation he held with "an important theoretical physicist" regarding the relevance of Rhine's research to the EPR paradox:

He: I am inclined to believe in telepathy.

I: This has probably more to do with physics than with psychology.

He: Yes. — [32]

Notwithstanding this interest, much of the subsequent research of this genre proved vulnerable to technical criticism and unpersuasive to the scientific mainstream.

Most recently, the more sophisticated information processing technology

that has advanced our understanding of the physical world over the last half century has also provided tools for addressing this class of anomalous phenomena with a methodological rigor unimaginable in the earlier parapsychological research. For example, over the period 1959 to 1987, some 832 experimental studies conducted by 68 investigators directly addressed the influence of human intention on the performance of a broad variety of random event generators. Meta-analytical assessment of these results yields strong statistical evidence for small but consistent anomalous effects that correlate with the intentions or desires of their operators [33], raising possible implications for experimental and theoretical study of many other probabilistic physical events, and for their technological applications. At the least, these findings should motivate performance and contemplation of yet more precise and extensive empirical studies.

The purpose of this article is to present a major body of new data that bears on this issue, acquired over twelve years of experimental study of anomalous human/machine interactions, conducted in an engineering laboratory context. Specifically, these studies have searched for possible correlations between the output data distributions of various random binary processes and the pre-stated intentions of attendant human operators. The history of this laboratory program, details of its instrumentation, protocols, data reduction and interpretation techniques, its attempts to model the observed effects, and the possible implications of the results for various regimes of basic science and technical applications have been described elsewhere [34-38]. Here we shall focus only on the empirical results and their individual and collective statistical merit.

II. Equipment and Protocol

The machine employed in the "benchmark" experiments of this program is a microelectronic random event generator (REG) driven by a commercial noise board (Elgenco #3602A - 15124), involving a reverse-biased semi-conductor junction, precision preamplifiers, and filters. The output spectrum of this noise source, essentially constant (± 1 db) from 50 Hz to 20 KHz, is clipped and further amplified to provide a randomly alternating flat-topped wave form of ± 10 volt amplitude with 0.5 μ sec rise and fall times which is gate-sampled at selectable regular intervals to yield a randomly alternating sequence of positive and negative pulses. A set number of these are then counted against a regularly alternating $+, -, +, -, \dots$ template, thereby differentially eliminating any distortion of randomness due to ground reference drift. The immediate and cumulative results are displayed via LEDs on the machine face and graphically on a computer screen, and transmitted on-line to a data management system. The balance of the device entails a variety of voltage and thermal monitors, redundant counters, and other fail-safe features that ensure its nominal operation and preclude tampering, and other security features are incorporated in the operational software. The machine is extensively and frequently calibrated in unattended operation, and is invariably found to reproduce the theoretic-

cal binomial combinatorial distributions having the appropriate means and standard deviations, with all higher moments and sequential correlations negligible, to statistical confidence more than adequate to support the claimed experimental correlations. A block diagram of this **REG** is shown in Figure 1; further technical details are available upon request.

For the benchmark experiments, this **REG** is set to generate *trials* of 200 binary samples each, which are counted at a rate of 1000 per second. The protocol requires individual human operators, seated in front of the machine but having no physical contact with it, to accumulate prescribed equal size blocks of data under three interspersed states of intention: to achieve a higher number of bit counts than the theoretical mean (HI); to achieve a lower number of bit counts than the theoretical mean (LO); or not to influence the output, *i.e.* to establish a baseline (BL). Data are collected in *runs* of 50, 100, or 1000 trials, depending on operator preference and protocol variations, and compounded over some number of experimental *sessions* into predefined data *series* of a specified number of trials, ranging from 1000 to 5000 per intention. Data processing is performed at the level of these individual series, which are regarded as the basic experimental units for interpretation and replication of any results. The essential criteria for anomalous correlations are statistically significant departures of the HI and/or LO series mean scores from the theoretical chance expectation and, most indicatively, the separation of the high- and low-intention data (HI-LO).

The order of the operator intentions is established either by their own choice

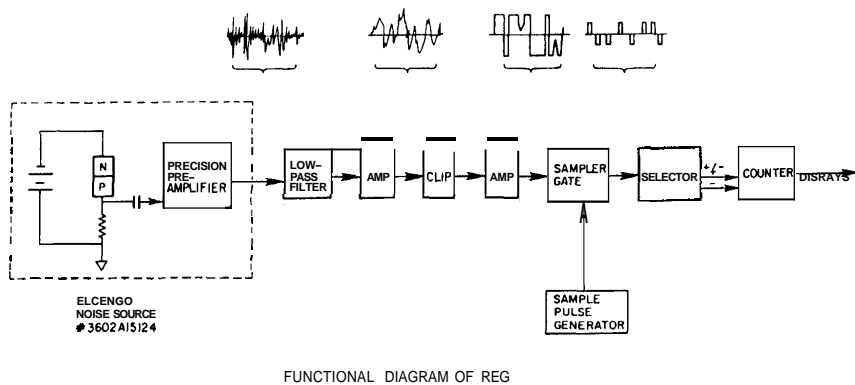


Fig. 1. Functional diagram of electronic Random Event Generator (REG) used in benchmark experiments. A commercial noise source based on a reverse-biased semi-conductor junction is processed to yield a randomly alternating sequence of positive and negative pulses, which are compared with a regularly alternating binary template. The number of coincidences from a specified number of samples are displayed immediately and cumulatively on the machine face and graphically on a computer screen, and are transmitted on-line to a data management system.

(volitional protocol) or by random assignment (instructed protocol), and is unalterably recorded in the database manager before the REG is activated by a remote switch. All subsequent data are automatically recorded on-line, printed simultaneously on a permanent strip recorder, and summarized by the operators in a dedicated logbook. Any discrepancy among these redundant records, or any fail-safe indication from the REG or its supporting equipment (both extraordinarily rare), invoke preestablished contingency procedures that preclude inclusion of any fouled data or any possible means of favorable data selection.

III. Primary Results

A. Collective Mean Shifts

Over a 12-year period of experimentation, 91 individual operators, all anonymous, uncompensated adults, none of whom claimed unusual abilities, accumulated a total of 2,497,200 trials distributed over 522 tripolar series in this benchmark experiment. Table 1 lists the overall results for the three categories of intention, HI, LO, and BL, and for the HI-LO separations, for comparison with the concomitant calibration data and the theoretical chance expectations. With reference to the symbol list below the table, the salient indicators are the mean shifts from the theoretical expectation, δ_μ , the corresponding z-scores, z_μ , and the one-tail probabilities of chance occurrence of these or larger deviations, p_μ . Also listed are the proportions of the 522 series yielding results in the intended directions, S. I. D., and the proportions of operators achieving results in the intended directions, O. I. D. (Note that as defined, δ , is expressed in units of bits/trial. We could equally well represent the effect size in absolute units of bits/bit processed, *i.e.* $\epsilon_\mu = \delta_\mu/2\mu_0$, which in turn differs by a factor of two from the common statistical effect size, $z_\mu/\sqrt{N_b} = \delta_\mu/\mu_0$, where N_b denotes the total number of bits processed. We shall henceforth use δ , and ϵ_μ more or less interchangeably, as befits the context).

The measures tabulated in Table 1 individually and collectively define the scale and character of the primary anomaly addressed in these studies, *i.e.* the statistically significant correlations of the output of this microelectronic random binary process with the pre-recorded intentions of a large pool of unselected human operators. Specifically to be noted is the overall scale of the effect, $O(10^{-4})$ bits inverted per bit processed; the somewhat higher deviation in the HI results compared to the LO; the slight departure of the BL results from both the theoretical chance expectation and the calibration value, and the negligible alterations in the variances of the score distributions. The overall figure of merit for the HI-LO separation, which is the postulated primary indicator, is $z_\mu = 3.81$ ($p_\mu = 7 \times 10^{-5}$).

The anomalous correlations also manifest in the fraction of experimental

TABLE 1
 Statistical data from benchmark REG experiments, listed for passive calibrations (CAL); Operator high intentions (HI), Low intentions (LO), and null intentions (BL); and HI-LO separations.

Parameter	CAL	HI	LO	BL	HI-LO
N_t	5,803,354	839,800	836,650	820,750	1,676,450
μ	99.998	100.026	99.984	100.013	
s_t	7.075	7.070	7.069	7.074	
σ_s	0.002	0.006	0.006	0.006	
δ_μ	-0.002	0.026	-0.016	0.013	0.042
σ_μ	0.003	0.008	0.008	0.008	0.011
z_μ	-0.826	3.369	-2.016	1.713	3.809
p_μ	0.409*	3.77×10^{-4}	0.0219	0.0867*	6.99×10^{-5}
S. I. D.		0.523	0.536	0.502†	0.569
O. I. D.		0.623	0.473	0.593†	0.516

KEY

N_t : Number of trials (200 binary samples each)

μ : Mean of trial score distribution

s_t : Standard deviation of trial score distribution

a_t : Measurement uncertainty (statistical) in the observed value of s_t ; $\sigma_s \equiv \sigma_0/\sqrt{2N_t}$ where $\sigma_0 = \sqrt{50}$ is the theoretical trial standard deviation.

δ_μ : Difference of mean from theoretical chance expectation;

$\delta_\mu \equiv \mu - \mu_0$ for HI and LO;

$\delta_\mu(HI - LO) \equiv \mu(HI) - \mu(LO) \equiv \delta_\mu(HI) - \delta_\mu(LO)$

σ_μ : Measurement uncertainty (statistical) in the observed value of δ_μ ; $\sigma_\mu = \sigma_0/\sqrt{N_t}$ for HI and LO;

$\sigma_\mu(HI - LO) = \sigma_0\sqrt{1/N_t(HI) + 1/N_t(LO)}$

z_μ : z-score of mean shift; $z_\mu \equiv \delta_\mu/\sigma_\mu$ (calculated with full precision from raw data values, not from the rounded values presented above in the table.)

p : One-tail probability of z_μ (CAL, BL two-tail)

S.I.D.: Proportion of series having z_μ in the intended direction

O.I.D.: Proportion of operators with overall results in the intended direction

* p-values for CAL and BL are two-tailed due to lack of intention.

† BL is treated as in intended direction when positive.

series in which the terminal results confirm the intended directions. For example, 57% of the series display HI-LO score separations in the intended direction ($z_s = 3.15$, $p = 8 \times 10^{-4}$). In contrast, the anomaly is not statistically evident in the 52% of individual operators producing databases in the intended

directions ($z_0 = 0.31$, $p = 0.38$), a feature having possible structural implications, as discussed below.

B. Cumulative Deviations

An instructive alternative display of these results is in the form of cumulative deviation graphs, wherein are plotted the accumulating total departures from the chance mean sequentially compounded by this group of operators in their HI, LO, and BL mean efforts over the long history of the experiment (Figure 2). The superimposed parabolic envelopes indicate the increasing width of one-tailed 95% confidence intervals about the theoretical mean as the database evolves. In this format, the deviant trends in the HI and LO performances appear as essentially random walks about shifted mean values, leading to steadily increasing departures from expectation. Consistent with the terminal values listed in Table 1, the average slopes of these two patterns of achievement, in units of bits deviation per bit processed, are roughly 1.3×10^{-4} and -7.8×10^{-5} respectively. Although local segments reflective of individual operators or particular periods of operation may differ somewhat from these overall effect sizes, as described below, this 10^{-4} order of magnitude tends to characterize virtually all of the anomalous correlations achieved in these experiments.

C. Count Distributions

Any structural details of the trial count distributions that compound to the observed anomalous mean shifts may hold useful implications for modeling such correlations. While no statistically significant departures of the variance, skew, kurtosis, or higher moments from the appropriate chance values appear

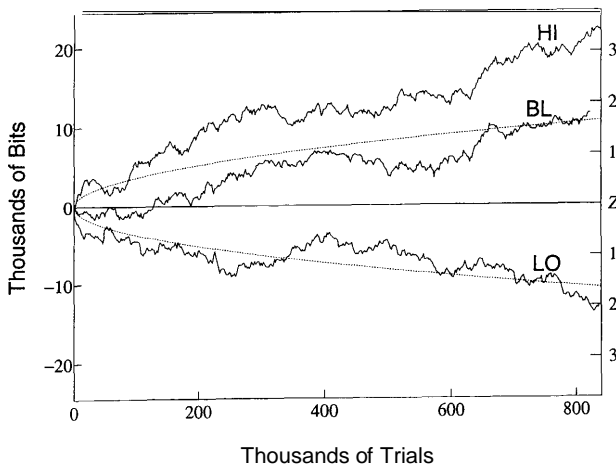
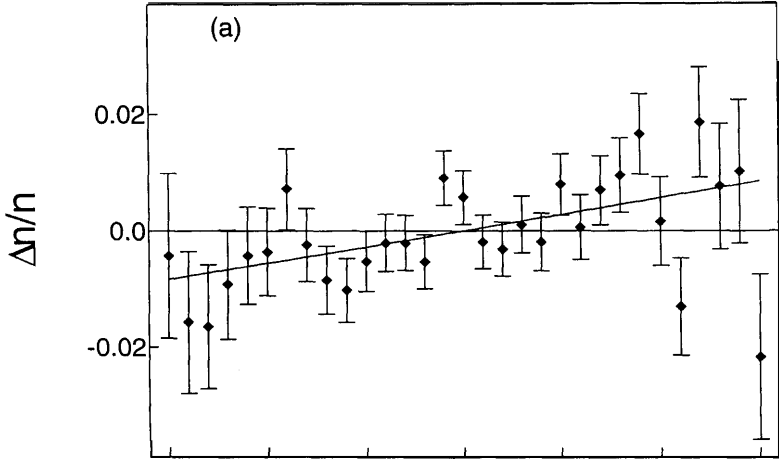
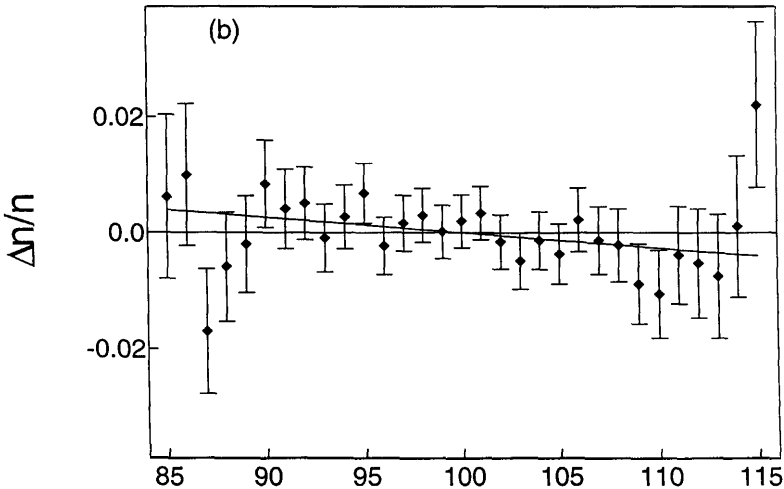


Fig. 2. Cumulative deviation graphs of benchmark REG results for HI, LO, and BL operator intentions. Parabolic envelopes are one-tail 95% confidence intervals about the theoretical chance mean. The scale on the right ordinate refers to the terminal z-scores.

in the overall data, regular patterns of certain finer scale features can be discerned. For example, deviations of the trial count populations, n , from their theoretical chance values, n_{io} , conform to statistical linear regressions of the form $\Delta n_i/n_{io} = 4\epsilon_\mu(\chi_i - \mu_0)$ where χ_i denotes the given trial count (e.g. 100, 102, 94, etc.), μ_0 is the theoretical chance mean of the full distribution (100), and $4\epsilon_\mu$ is the slope of the linear regression fit. Figure 3 depicts this effect graphi-



3a.



3b.

Fig. 3. Normalized deviations of benchmark REG individual count populations from chance expectations: (a) HI intention data: linear fit, $z_1 = 3.27$; quadratic correction, $z_2 = 0.69$; (b) LO intention data: linear fit, $z_1 = 1.55$; quadratic correction, $z_2 = 0.48$.

cally for the database of Table 1 and Figure 2. Such functional behavior is consistent with a simple displacement of the chance Gaussian distribution to the observed mean value or, equivalently, to a shift in the elementary binomial probability from the exact theoretical value of 0.5 to $(0.5 + \epsilon_\mu)$ [39]. Given the consistency of all other features of the distributions with chance expectation, this suggests that the most parsimonious model of the anomalous correlation is between operator intention and the binary probability intrinsic to the experiment.

D. Individual *Operator Effects*

Given the correlation of operator intentions with the anomalous mean shifts, it is reasonable to search the data for operator-specific features that might establish some pattern of individual operator contributions to the overall results. Unfortunately, quantitative statistical assessment of these is complicated by the unavoidably wide disparity among the operator database sizes, and by the small signal-to-noise ratio of the raw data, leaving graphical and analytical representations of the distribution of individual operator effects only marginally enlightening. For example, Figure 4 deploys the 91 individual operator HI-LO mean shift separations as a function of their various data base sizes. Superimposed are the theoretical mean value, the mean value of the composite data, and the 1.64σ ($p_\mu = 0.05$) deviation loci with respect to these two means. Of interest here are the ratios of positive and negative points about the theoretical and empirical means, their dependence on data base size and on operator gender, and the positions and genders of the outliers.

The limited number of operator data points make density plots of these mean shift data sensitive to the bin sizes and locations selected, but Figure 5 compares one such display with appropriate theoretical distributions centered on the chance and empirical mean values. The attached chi-squared values indicate some preference for the latter model, but for these data the direct z_μ calculation underlying Table 1 is a far more accurate indicator of the anomalous mean shift. Attempts to interpret the operator distribution of z-scores, rather than mean shifts, suffer from the same limitations of available data points, and are similarly inconclusive.

Given the specification of the experimental series as the pre-established unit for data interpretation, and the significantly larger fraction of series having HI-LO differences in the intended directions (Table 1), it is also reasonable to search for indications of data structure in the distribution of series scores achieved by all operators. Since a total of 522 such data units are available, the resolution of mean shift and z-score distributions is considerably better here, but as shown in Figure 6, beyond more clearly confirming the overall shifts of the mean, further identification of structural detail remains speculative. This situation is further confused by the obvious operator gender disparity in the data, as highlighted in the inset table on Figure 4, and discussed below.

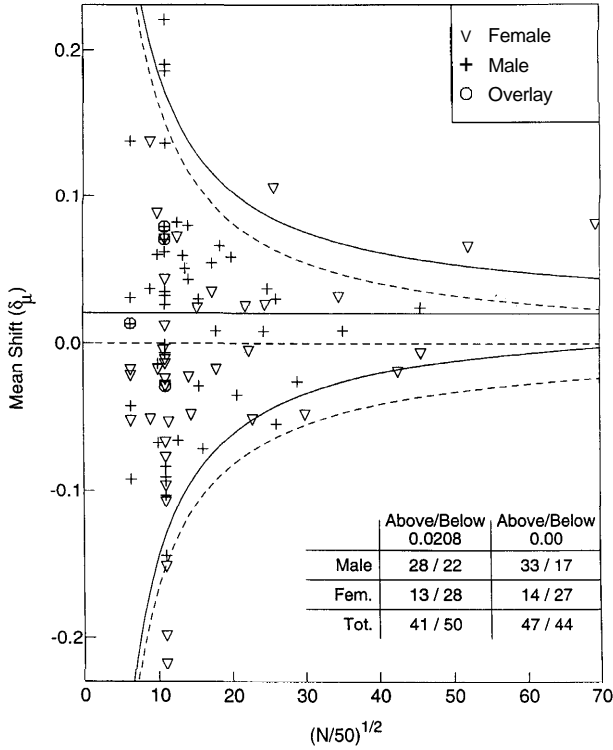


Fig. 4. Deployment of 91 individual operator HI-LO mean shift separations achieved in the benchmark REG experiments, as a function of their database sizes. The inset table highlights the imbalances in male and female operator performance with respect to the empirical and theoretical chance mean-shift values.

IV. Secondary Correlations

Possible secondary correlations of effect sizes with a host of technical, psychological, and environmental factors *e.g.*, the type of random source; the distance of the operator from the machine; operator gender; two or more operators attempting the task together; feedback modes; the rate of bit generation; the number of bits sampled per trial; the number of trials comprising a run or series; the volitional/instructed protocol options; the degree of operator experience; and others have been explored to various extents within the course of these experiments, and in many other related studies not discussed here. Very briefly, qualitative inspection of these data, along with a comprehensive analysis of variance [40] indicate that most of these factors do not consistently alter the character or scale of the combined operator effects from those outlined above, although some may be important in certain individual operator performance patterns. The few potentially important exceptions to this generalization that have been identified are described in the following paragraphs.

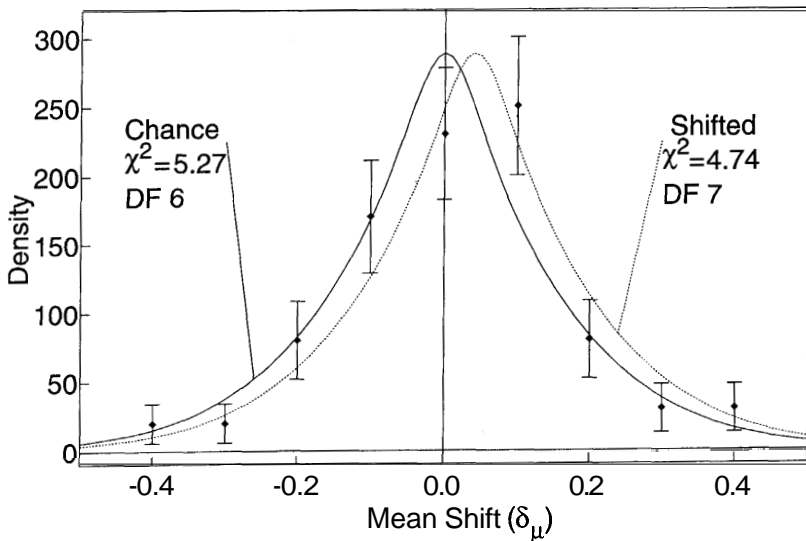


Fig. 5. Density plot of 91 individual operator HI-LO mean shifts achieved on benchmark REG experiments, superimposed on theoretical distributions centered on the chance and empirical mean-shift values. These two comparison curves are constructed as the sums of 91 operator normal distributions, each of observation error $\sigma_i \propto 1/N_i$ where N_i is the individual database size. The "chance" curve assumes all individual effect sizes are zero; the "shifted" curve assumes all are the same as the composite effect size. The latter assumption yields a better χ^2 fit.

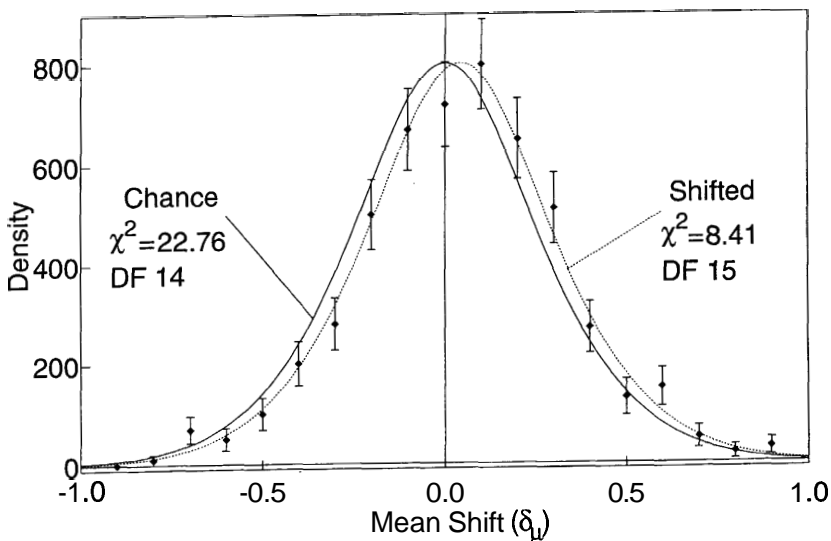


Fig6 Density plot of 522 series HI-LO mean shifts achieved on benchmark experiments, superimposed on theoretical distributions centered on the chance and empirical mean-shift values (constructed as in Fig. 5).

A. Gender-Related *Effects*

Segregation of the total REG database described above into male and female operator components reveals several striking disparities. As evident in Figure 4, although three of the female operators have produced the largest individual z-scores, the overall correlations of mean shifts with intention are much weaker for the females than for the males. In fact, while a majority of the males succeed in both directions of effort, most of the females' low intention results are opposite to intention. Specifically, some 66% of the male operators succeed in separating their overall HI and LO scores in the intended direction, compared to only 34% of the females. In other words, there is some indication that the total operator performance distribution has three components: a) three outstanding female datasets; b) 38 female datasets indistinguishable from a chance distribution; and c) 50 well-distributed male datasets compounding to significant positive performance. Many other aspects of the gender-related disparities are detailed in Ref. [41].

B. Device Dependence

The sensitivity of the anomalous correlations to the particular random source employed or to its form of implementation into an experimental device has been extensively explored via a variety of machines and protocols [36, 40, 41]. In the simplest variants, the commercial microelectronic noise diode in the benchmark configuration was replaced by identical and similar units, with no detectable changes in the character of the results. In a more substantial and, as it turned out, more critical set of modifications, the physical noise source was replaced by three distinctly different pseudorandom sources:

- 1) A pseudorandom-number generating algorithm included in the Borland Turbo Basic programming package was implemented on an IBM AT-286 computer to provide binary strings that could be counted and displayed in the same formats as the benchmark experiments. More specifically, the floating-point numbers provided by the Borland function, which distribute uniformly over the interval 0 to 1, were converted into bits by assigning 1 to all values above 0.5, and 0 to all values below. The initiating seeds were obtained by starting a microsecond clock when the operator prompts first appeared on the screen, and stopping it when the operators responded by pressing a key. The accumulated values were then added to the number of seconds since midnight to compound the seeds. In performing these experiments, the operators had the options of digital, digital cumulative, or graphical cumulative deviation displays on the monitor, akin to those available on the benchmark version.
- 2) The benchmark equipment was modified to allow replacement of the Elgenco noise source by a hard-wired electronic shift register containing 31 flip-flops comprising a sequence length of over 2×10^6 steps. This generator produced strictly deterministic sequences from the same ini-

tial seed that, at a sampling rate of 1000 Hz, recycled roughly every 60 hours, far exceeding the length of any single experimental session. From the operator's perspective, all other aspects of the protocol, machine operation, and feedback display were identical to those of the benchmark experiments.

- 3) A random element was overlaid on the pseudorandom processor just described by introducing an asynchronous shift frequency for the register, driven by an analog element that swept from a few kHz to a few tens of kHz over a period of several minutes. This unpredictable component of the sampling imbued the device with a complex combination of random and pseudorandom characteristics.

As discussed further below, when source #3, which retains some physically random features, is utilized, statistically significant correlations of results with operator intention, comparable to those seen in the benchmark experiments, continue to appear. For the strictly deterministic sources #1 and #2, however, no such correlations are observed.

A more substantial extension of the experimental concept employs a large scale mechanical device called a "Random Mechanical Cascade" (RMC), in which 9000 \times 3/4" dia. polystyrene spheres trickle downward through a quincunx array of 330 \times 3/4" dia. nylon pegs, whereby they are scattered into 19 collection bins in a close approximation to a Gaussian population distribution. In this experiment, operators endeavor to shift the mean bin population to the right or left, or to exert no intention in randomly interspersed trials. The large databases from this experiment display a similar size and character of anomalous correlations to those of the smaller scale random source experiments, and similar count population and other structural details [42].

C. Series Position Effects

While it might be reasonable to expect that operators' proficiency at these experimental tasks would improve with increasing experience, no systematic learning tendencies are evident in the data. Rather, the progression of the anomalous effect sizes as a function of the number of series completed by the operators is found to take the somewhat unanticipated form shown in Figure 7. Namely, when the mean shifts obtained by all operators on their respective first, second, third,... series are plotted against that series ordinal position, a peak of initial success is followed by sharp reduction on the second and third series, whereafter the effect gradually recovers to an asymptotic intermediate value over the higher series numbers [43]. This pattern obtains, with minor disparities, for the overall HI, LO, and HI-LO data, but not for the baselines. It also appears in a majority of the individual operator databases having five or more series. The interpretation of this pattern on psychological or physical grounds can only be speculative at this point, but its ubiquitous appearance clearly complicates any consistency or replicability criteria.

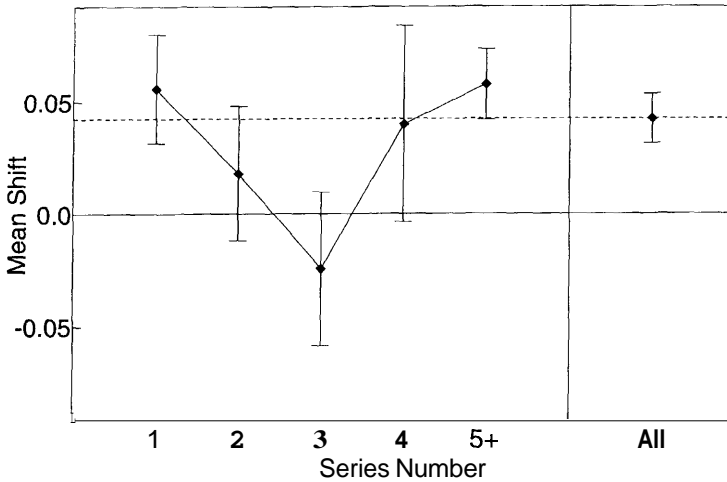


Fig. 7. Benchmark REG HI-LO mean separations achieved by all 91 operators on their first, second, third... experimental series. The value at 5+ subsumes all series beyond the fourth. The value at "all" is the grand average of all data.

D. Distance and Time Dependence

The dependence of the effect sizes on the distance of the operator from the machine could also be an important indicator of fundamental mechanism. Actually, no such dependence has been found over the dimensions available in the laboratory itself. More remarkably, these operator/machine aberrations continue to manifest in a substantial body of experiments wherein operators are physically separated from the devices by distances of up to several thousand miles, again with no statistically detectable dependence of the effect sizes on the degree of separation. Rather, the results of some 396,000 trials per intention conducted under this "remote" protocol, wherein the device is run unobserved at prearranged times by staff members who remain blind to the operators' intentions, are very similar in character to those of the local experiments, including the scale of effect, and the relatively larger results under HI intentions compared to LO [44].

In a subset of this remote database, comprising some 87,000 trials per intention, the operators address their attention to the machine's operation at times other than those at which the data are actually generated. Such "off-time" experiments have ranged from 73 hours before to 336 hours after machine operation, and display a scale and character of anomalous results similar to those of the locally generated data, including gender effects and count population distortions. In fact, the overall mean shift in the high-intention efforts in these "off-time" remote experiments is twice as large as that in the "on-time" remote data, although this difference is not statistically significant, given the smaller size off-time database. As with the distance separations, no dependence of the

yield on the magnitude of the temporal separations is observed over the range tested. Comparable remote and off-time results are found in the RMC experiment, as well.

E. Operator Strategy and Psychological Correlates

Although no systematic assessment of any of the multitude of potentially relevant psychological parameters characterizing the operators has been attempted, on the basis of informal discussions, casual observations of their styles, occasional remarks they record in the experimental logbooks, and our own experiences as operators, it is clear that individual strategies vary widely. Most operators simply attend to the task in a quiet, straightforward manner. A few use meditation or visualization techniques or attempt to identify with the device or process in some transpersonal manner; others employ more assertive or competitive strategies. Some concentrate intently on the process; others are more passive, maintaining only diffuse attention to the machine and diverting their immediate focus to some other activity, such as glancing through a magazine, or listening to music. We find little pattern of correlation of such strategies with achievement. Rather, the effectiveness of any particular operational style seems to be operator-specific and transitory; what seems to help one operator does not appeal to another, and what seems to help on one occasion may fail on the next. If there is any commonality to be found in this diversity of strategy, it would be that the most effective operators tend to speak of the devices in frankly anthropomorphic terms, and to associate successful performance with the establishment of some form of bond or resonance with the device, akin to that one might feel for one's car, tools, musical instruments, or sports equipment.

V. Combined Results

A summary of the results from all of the experimental excursions noted above, along with a few others not specifically mentioned, is presented in Table 2. Listed here are the number of complete experimental series, N_s ; the number of binary samples processed, N_b ; the z-scores based on the difference of the HI-LO means, z_μ ; the statistical effect sizes per bit, here reconstructed from ϵ_μ , *i.e.* $\epsilon_\mu = z_\mu / 2\sqrt{N_b}$, as discussed in Section 111-A; and the one-tail probabilities associated with z_μ , p . Note that the table segregates those experiments having truly random sources from those whose sources are deterministic pseudorandom. Of the former, only the two with the smallest data sets fail to contribute positively to the overall HI-LO separation; in fact, all but three independently achieve significance by the $p < .05$ criterion. In contrast, none of the deterministic experiments show any correlations with operator intention, despite their identical protocols and data processing, and their similar operator pools.

Combination of data from all of these experiments into an overall statistical

TABLE 2
HI-LO mean shift statistics for all REG-class experiments, as defined in Key below.

Expt.	N_s	N_b	z_μ	$\epsilon_\mu (\times 10^5)$	P_μ
Random Experiments					
D_L	522	3.35×10^8	3.809	20.8 ± 5.5	6.99×10^{-5}
D_R	212	1.83×10^8	2.214	16.4 ± 7.4	0.0134
PR_{LR}	46	4.94×10^7	2.765	39.3 ± 14.3	0.00284
D_C	45	3.62×10^7	1.635	27.2 ± 16.6	0.0510
D_{2K}	44*	3.25×10^8	2.718	15.1 ± 5.6	0.00328
D_{20}	20	1.64×10^6	-0.956	-74.7 ± 78.1	0.830
MC_L	87	4.07×10^8	3.891	19.3 ± 5.0	4.99×10^{-5}
MC_R	26	9.32×10^7	2.139	22.2 ± 10.4	0.0162
MC_C	12	4.32×10^7	-0.040	-0.6 ± 15.2	0.513
Deterministic Experiments					
PD_{LR}	23	9.20×10^6	-1.390	-45.8 ± 33.0	0.918
AP_L	396	1.58×10^8	-0.646	-5.1 ± 7.9	0.741
AP_R	86	3.44×10^7	0.335	5.7 ± 17.0	0.369
AP_C	8	3.20×10^6	0.427	23.9 ± 55.9	0.335

KEY

- N_s : Number of series
 N_b : Number of binary samples
 z_μ : z-score of mean shift
 ϵ_μ : Statistical effect size per bit; $\epsilon_\mu \equiv z_\mu / \sqrt{N_b}$. (See text)
 p : One-tail probability of z_μ
 D_L : Diode REG, local
 D_R : Diode REG, remote (includes off-time data)
 PR_{LR} : Pseudorandom REG (hardwired with random element), local and remote
 D_C : Diode REG, co-operator data
 D_{2K} : Diode REG, 2000-sample trials.
 D_{20} : Diode REG, 20-sample trials
 MC_L : Random Mechanical Cascade, local
 MC_R : Random Mechanical Cascade, remote (includes off-time data)
 MC_C : Random Mechanical Cascade, co-operator
 PD_{LR} : Pseudorandom REG (hardwired, no random element), local and remote
 AP_L : Algorithmic pseudorandom REG, local
 AP_R : Algorithmic pseudorandom REG, remote (includes off-time data)
 AP_C : Algorithmic pseudorandom REG, co-operator data

* This dataset includes 7 series by 2 operators that used the PR source rather than the D source. Since there is no detectable difference between the two subsets, they are combined as a single table entry.

figure of merit is complicated by the major disparities in the various database sizes, some distinctions in the protocols and measureables, the absence of theoretical expectations in the RMC experiments, the pervasive gender disparities and the HI vs. LO asymmetries associated with them, and the ambiguities associated with the interplay of series position effects with individual operator database sizes. However, a number of meta-analytic techniques can be invoked to provide composite estimates for the overall likelihood of the entire collection of anomalous mean shifts. For example, one could simply compound the values of z_μ listed in Table 2 into an unweighted composite value. Alternatively, one could weight the individual experiment z_μ values by the numbers of series in the databases, or by the numbers of binary samples each contains. Finally, one could combine results at the level of p , values, rather than z_μ , using a method proposed by Rosenthal [45]. In a separate paper, we have presented detailed arguments for preference of the sample-weighted recipe for this type of data combination [46] although, as displayed in Table 3, the quantitative disparities among all of these methods are insufficient to obscure the magnitude of the bottom-line results. Again note that by any of the recipes the ensemble of experiments utilizing physically random sources compound to overwhelming statistical likelihood, while the deterministic group lies well within chance expectation.

A similar sharp discrimination appears in both the composite series success rate and operator success rate criteria. In the former, 58.4% of the total of 1014 random source experimental series show a positive HI-LO separation ($z_s = 5.339$, $p_s = 4.68 \times 10^{-8}$), compared to 49.7% for the deterministic group ($z_s = -0.132$, $p_s = 0.55$). In the latter, 57.3% of the 199 operators of the random source experiments succeed in splitting their HI and LO results in the intended direction ($z_o = 2.056$, $p_o = 0.0199$), compared to 45.7% of the 46 operators of the deterministic group ($z_o = -0.590$, $p_o = 0.722$). By either criterion, the success rates are broadly distributed over the various random source experiments, with eight of the nine contributing positively to both the series and operator composites.

The strong distinction between the results using random and deterministic sources may help discriminate among various theoretical models that have been proposed for effects of this genre. For example, the "Decision Augmentation Theory" proposed by May *et al.* [47], which predicts that the nature of

TABLE 3

Combined HI-LO z-scores of all REG-class experiments computed by four methods described in the text references, (with associated one-tail probabilities of chance occurrence in parentheses).

Method	Random Expts.	Determ. Expts.	Both
Unweighted	6.058(6.88 x 10 ⁻¹⁰)	-0.637(0.738)	4.687(1.38 x 10 ⁻⁶)
Series Weighted	6.588(2.22 x 10 ⁻¹¹)	-0.671(0.749)	4.980(3.18 x 10 ⁻⁷)
Data Weighted	7.180(3.50 x 10 ⁻¹³)	-0.671(0.749)	6.492(4.24 x 10 ⁻¹¹)
Rosenthal	6.445(5.80 x 10 ⁻¹¹)	-0.714(0.762)	5.812(3.09 x 10 ⁻⁹)

the source should be irrelevant to the presence or scale of the effect, is clearly incompatible with this observed difference in performance. (A more detailed and quantitative review of the implications of this database for the "D.A.T." model can be found in reference [48]).

VI. Replicability Requirements

From time to time, the experiments reported here have been assessed, both formally and informally, by a number of critical observers, who have generally agreed that the equipment, protocols, and data processing are sound [49]. Frequently, however, the caveat is added that such results must be "replicated" before they can be fully accepted, with the replication criteria variously defined to require strict preservation of all technical and procedural details, or to allow more flexible similarities in equipment and protocols. It is our opinion that for experiments of this sort, involving as they clearly do substantial psychological factors and therefore both individual and collective statistical behaviors, to require that any given operator, on any given day, should produce identical results, or that any given operator group should quantitatively replicate the results of any other, is clearly unreasonable. Rather more apt would be such criteria as might be applied to controlled experiments in human creativity, perception, learning, or athletic achievement, where broad statistical ranges of individual and collective performance must be anticipated, and results therefore interpreted in statistically generic terms.

By such criteria, the experiments outlined here can be claimed both to show internal consistency, and to replicate results of similar experiments in many other laboratories. For example, the statistical consistency of individual operator performances across multiple experimental series that compound to their particular positions on Figure 4 defines one level of internal replicability. The systematic accumulation of intention-correlated effects across many operators, as displayed in Table 1, defines a second level. The consistently similar results of the same group of operators on the various extensions of the basic REG experiment to other protocols, noise sources, and categorically different random physical devices, shown in Table 3, establishes a third, inter-experiment level of replicability.

With respect to inter-laboratory reproducibility, it should first be noted that the experiments reported here were originally undertaken as an attempt to replicate previous studies by Schmidt [50] and others [51], albeit with modifications in design and equipment that would respond to various criticisms and allow more rapid accumulation of very large quantities of data. Our results indeed reinforce this earlier work in confirming the existence, scale, and character of anomalous correlations with pre-stated operator intentions. On a broader front, the previously mentioned quantitative review of 30 years of research of this genre, covering more than 800 experiments reported by 68 principal investigators, including ourselves, concludes that despite the historical improve-

ment in experimental quality, a statistically constant anomalous effect size has pervaded most of the results [33].

VII. Theoretical Modeling

Any attempts to model phenomena like those reported here must be immensely complicated by the evidence that human volition is the primary correlate of the observed anomalous physical effects, and thus that some proactive role for consciousness must somehow be represented. This challenge is compounded by the absence of clear-cut psychological or physiological indicators, and by the lack of demonstrable space and time dependence. While a variety of attempts to combine conventional psychological and neurophysiological concepts with established physical and mathematical formalisms, such as electromagnetic theory, statistical thermodynamics, quantum mechanics, geophysical mechanics, and hyperspace formalisms have been proposed [50], few of these propositions seem competent to accommodate the salient features of the empirical data, let alone to survive critical scientific and epistemological criteria.

Rather, a more comprehensive approach to formulation of the interaction of consciousness with the physical world seems requisite. Over the past two decades, a growing number of theoretical physicists and philosophers of science have addressed the problem of consciousness from this broader perspective, and have offered an assortment of more sophisticated models which may eventually prove effective for dialogue with the empirical results. Some of these apply quantum physical concepts and formalisms to neurological processes and functions [28, 53]. Others employ non-linear systems concepts underlying information science, chaos, and complexity theories to provide degrees of freedom to accommodate the intervention of consciousness into physical processes [54]. Still others propose a holistic complementarity between the epistemology of human experience and the ontology of the physical world [37]. While each of these approaches at least acknowledges the problem, the chasm between the role of consciousness and self-consistent physical theory is far from bridged and, given its troublesome empirical and conceptual aspects, will require much more visionary work from both the experimental and theoretical sides.

VIII. Extended Experiments

Since completion of the databases described above, a number of new experiments involving substantially different physical processes, modes of feedback, and protocols have been deployed in the hope of better identification of the most critical physical and psychological properties bearing on the anomalous phenomena. For example, similar but more compact REG units are being used to drive an "ArtREG" experiment, wherein two competing scenes are superimposed on a computer screen with relative illumination determined

by the accumulating balance of binary events from the noise source. The task of the operator is to cause one pre-selected scene to dominate over the other, without current knowledge of the binary balance. In another experiment, a compact REG drives a large musical drum to produce a random alternation of equally spaced loud and soft beats or, in another variant, a random alternation of long and short intervals of equal amplitude. The goal of the operator in either version is to impose some regularity of pattern on the audible beat stream. Analysis programs compute the overall entropy of the bit stream and search for repetitive sub-patterns indicative of an imposed cadence. Other devices, such as classical single and double slit diffraction equipment, and REGs that alternate digital and analog data sampling, or that compare two grossly different bit-sampling rates, help search for further physical correlates. In a complementary effort to access the importance of operator feedback modalities, various aesthetically engaging systems, such as a large linear pendulum or an upward bubbling water fountain, have been employed, along with a mobile robot driven in random motion by an on-board REG. Although the databases from these new experiments are not yet sufficient to provide robust quantitative results, various anomalous effects correlated with operator intention are apparent in the structural details of their data distributions, of comparable scales to those seen in the direct REG interactions.

IX. Summary

The extensive databases described above, comprising more than 1500 complete experimental series generated over a period of 12 years in rigid tripolar protocols by over 100 unselected human operators using several random digital processors, display the following salient features:

- 1) Strong statistical correlations between the means of the output distributions and the pre-recorded intentions of the operators appear in virtually all of the experiments using random sources.
- 2) Such correlations are not found in those experiments using deterministic pseudo-random sources.
- 3) The overall scale of the anomalous mean shifts are of the order of 10^{-4} bits per bit processed which, over the full composite database, compounds to a statistical deviation of more than 7σ ($p \approx 3.5 \times 10^{-13}$).
- 4) While characteristic distinctions among individual operator performances are difficult to confirm analytically, a number of significant differences between female and male operator performance are demonstrable.
- 5) The series score distributions and the count population distributions in both the collective and individual operator data are consistent with chance distributions based on slightly altered binary probabilities.

- 6) Oscillatory series position patterns in collective and individual operator performance appear in much of the data, complicating the replication criteria.
- 7) Experiments performed by operators far removed from the devices, or exerting their intentions at times other than that of device operation, yield results of comparable scale and character to those of the local, on-time experiments. Such remote, off-time results have been demonstrated on all of the random sources.
- 8) Appropriate internal consistency, and inter-experiment and inter-laboratory replicability of the generic features of these anomalous results have been established.
- 9) A much broader range of random-source experiments currently in progress display a similar scale and character of anomalous results.

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