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A Linear Pendulum Experiment: Effects of Operator Intention on Damping Rate

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Abstract—An attractive pendulum consisting of a two-inch crystal ball suspended on a fused silica rod is the focus of an experiment to measure possible effects of conscious intention on an analog physical system. The pendulum is enclosed in a clear acrylic box, and provided with a computer controlled mechanical system to release it from the same starting height in repeated runs. A high speed binary counter registers interruptions of photodiode beams, to measure velocities at the nadir of the pendulum arc with microsecond accuracy. In runs of 100 swings, taking about three minutes, operators attempt to keep swings high, i.e. to decrease the damping rate (HI); to reduce swing amplitude, i.e. to increase the damping rate (LO); or to take an undisturbed baseline (BL).

Over a total of 1545 sets, generated by 42 operators, the HI – LO difference is significant in the direction of intention for five individuals, and the difference between intention and baseline runs is significant and positive for five other operators. The overall HI – LO difference is reduced to non-significance by strong negative performances from several operators, four of whom have comparably large scores in the direction opposite to intention. Analysis of variance reveals significant internal structure in the database (main effects $F_{4,\ 189}= 2.845$, $p = .025$). Subset comparisons indicate that male operators tend to score higher than females, and that randomly instructed trials tend toward higher scores than volitional trials, especially for male operators. Trials generated with the operator in a remote location have a larger effect size than the local trials.

While direct comparisons are not straightforward, it appears that effects of operator intention on the pendulum damping rate may be similar in magnitude and style to those in other human/machine interaction experiments. Although this result fails to support an experimental hypothesis that the analog nature of the pendulum experiment would engender larger effect sizes, it does confirm a basic similarity of consciousness effects across experiments using fundamentally different physical systems.

Introduction

Experiments using electronic random event generators (REG's) of several types (Nelson, Dunne, & Jahn, 1984; Jahn, Dunne, & Nelson, 1987; Nelson et al., 1991), as well as a random mechanical cascade (RMC) experiment, (Dunne, Nelson, & Jahn, 1988) have provided evidence for anomalous correlations of the performance of such physical devices with operator intention. In particular, shifts of the empirical distribution means have been found to be significantly correlated with volitionally or randomly assigned intentions to influence them. Although these experiments are based on substantially differing physical processes, they are all essentially digital or discrete in nature, with binary positive or negative increments in the experimental measures as the target of the operator's intentions. To increase its generality, this genre of research has been extended into the analog domain via an experiment that has potentially greater sensitivity to operator interaction because of its appealing aesthetic qualities and the continuously variable nature of the measurable. The device is a classical linear pendulum, suitably instrumented to provide precise measurement of its dynamic performance and to give appropriate feedback to operators. Of the many possible configurations, a free-swinging pendulum enclosed in a clear acrylic box was chosen for development, with the damping rate selected as the primary measurable. Volunteer operators, none of whom claim special abilities, are directed to sit quietly about one and a half meters from the pendulum and focus attention on it with either a HI intention, defined as keeping the swings high (corresponding to a decrease in the damping rate), or a LO intention, defined as keeping the swings low (corresponding to an increase in the damping rate), or to take a baseline (BL), wherein there is no effort to change the pendulum behavior. These HI, LO, and BL conditions are accumulated in contiguous sets of three runs, which are then compounded into series which are considered to be independent replications of the experiment.

Equipment

The pendulum bob is a clear quartz crystal ball two inches in diameter attached to a 30-inch long, clear fused silica rod, chosen for its extremely small coefficient of thermal expansion. The upper end of the rod is mounted in brass and aluminum fixtures holding bearing elements. In pilot studies, three types of precision bearings were tested, in a search for optimum reliability and minimum bearing contributions to damping forces. The final choice for the formal experiment was a miniature dual-race ball bearing system that is highly reliable, with low friction and no detectable sensitivity to wear or thermal expansion. These bearings contribute only a small fraction (about 7% at maximum arc) of the composite damping forces; the rest are presumably aerodynamic. The bearing system is supported by a massive aluminum bar, 2.5 inches square, which is fixed to a vertically oriented, machined aluminum plate, 1.5 inches thick, attached in turn to the aluminum baseplate of the experiment. The entire pendulum assembly is enclosed in a clear acrylic box, 24 inches square by 36 inches tall, which stands on a massive support table that encloses the electronic hardware. Figure 1 is a photograph of the device from the oper-

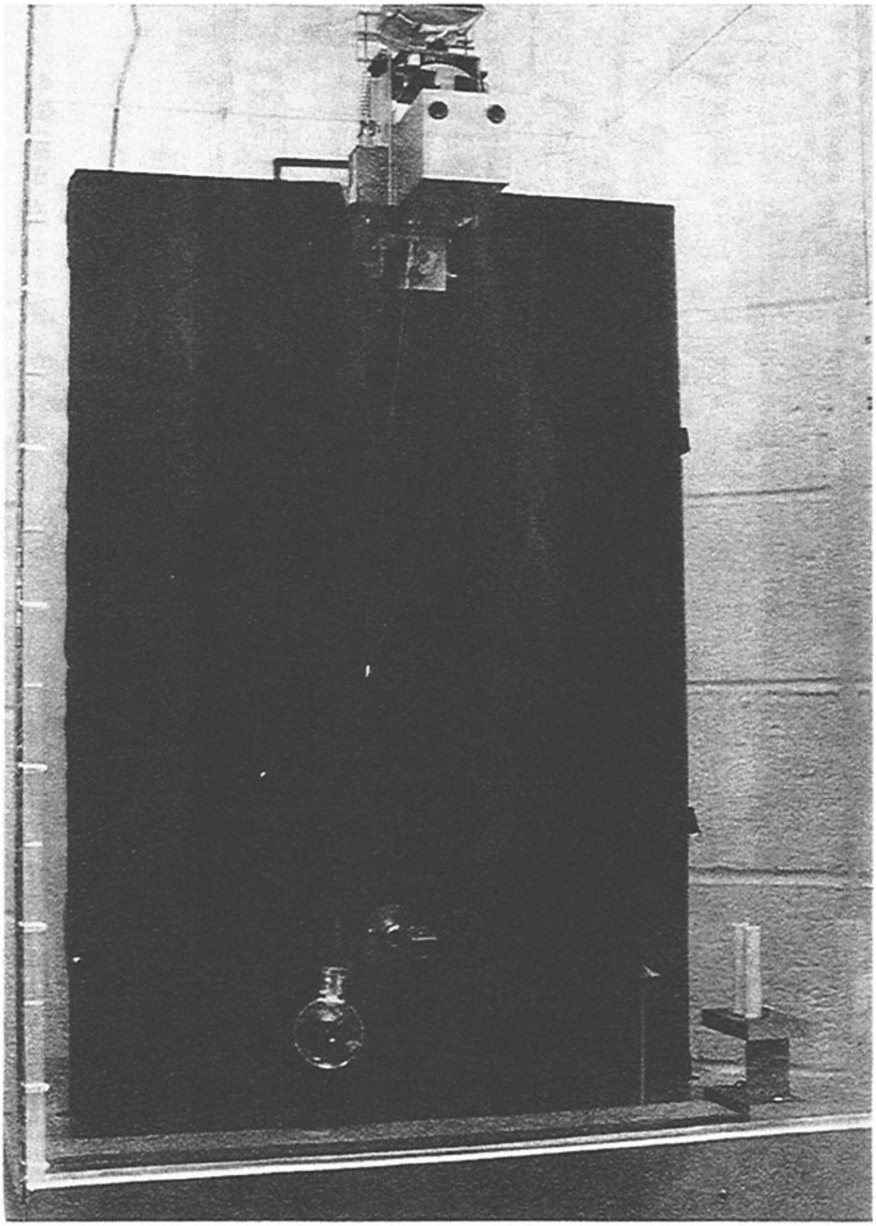

Figure 1: The Linear Pendulum Experimental Device

ator's point of view, and Figure 2 is a close-up photograph showing the bob at the beginning of a run.

A stepper motor, mounted behind the vertical plate and operated by a micro-controller, moves an arm that pushes the pendulum bob up to a start cradle on

Figure 2: The Primary Components of the Linear Pendulum

the right side of the case. In the photo, the bob has just been released from the cradle by the mechanical arm, which may be seen accelerating ahead of the bob. Behind the bob is a conical shield over a thermistor, and at the far left is the photodiode system. Figure 3 (Data Procesing) sketches the mechanical details of the measurement system.

To initiate a run, the arm is rapidly moved to its parking position on the opposite side of the case, releasing the pendulum to swing freely through an arc of about 35 degrees. A double blade is mounted on the rod near the bob, protruding toward the backplate, so that the two leading edges, separated by about one centimeter, pass through photodiode pairs mounted on a stalk attached to the backplate. The interruptions of the photodiode beams are timed with 50 nanosecond resolution, using a binary counter with a 20 megahertz clock rate, and the times are recorded as raw data in computer files, together with computed velocities and changes of velocity (damping), and identifying index information. It should be noted that although the damping rate is the specified target of operator intention, we cannot exclude the possibility that the experimental results could reflect influences on other elements of the system, such as the measuring circuit, which includes both digital and analog components.

Direct feedback to the operator during the run is provided by light projected along the fused silica rod to the crystal bob, the color of which is changed by a graduated filter whose position is controlled by the magnitude and sign of cumulated differences between the ongoing run and the preceding baseline run.

The operation of the experiment is entirely controlled by computer software that communicates with the physical apparatus through a GPIB IEEE-488 interface and EPROM based micro-controller code. The program is written in GWBASIC to run on an 80286-based PC; it manages the experiment, including all operator activity, and maintains data files with their corresponding index. For data security and integrity, a redundant hardcopy of blocks of averaged raw data is made to provide confirmation of the primary data and protection against its loss. In addition to the hardcopy, a complete copy of the data is written to a floppy disk as well as to the hard disk. A set of automatic instruments (Sensor Instruments Co., Inc.) records temperature, humidity, and barometric pressure, and these parameters are included in the index for each run.

The massive pendulum structure itself is level and stable relative to the floor and building, and while building vibration or the effects of passing traffic, etc., transmitted through the concrete slab floor may in principle affect data at a statistically detectable level, the experimental design ensures that such effects will not be correlated with conditions of intention or any secondary parameters. Physical movements of the operators, such as swaying, tapping, rocking, and head nodding in response to the pendulum, are a potential influence if they should be mechanically coupled to the pendulum via the floor or air movement. The latter possibility is largely obviated by the complete enclosure, but protection from mechanical interference, such as stamping on the floor or touching the pendulum case, or acoustical disturbance such as shouting or whistling, is currently provided only by operator training and integrity. However, testing indicates that the most prominent effect, and indeed the only detectable change due to regular, synchronized mechanical interference (e.g., tapping on the case), is to increase the variance of data within runs, leading to increased standard error and hence more conservative tests of differences between runs. Complete protection from all such spurious sources of effect is inherent in the subset of the database where operators are in a remote location during the run. All of these are run automatically, often when no one is in the laboratory, and in any case the staff do not know the order of the operator intentions, so that there is no possibility for conscious or unconscious introduction of correlated vibrations. Finally, a fail-safe threshold check is incorporated to detect rampant outliers caused by bearing malfunction or other major artifact, but in the formal database accumulated since the installation of the precision dual-race bearings, no such threshold events have occurred.

Procedure

Data are taken in runs of 100 full swings and the pendulum period is about 1.8 seconds; a run thus takes about three minutes, plus time for writing files and recording summary information. The three intentions are combined in contiguous sets of three runs, wherein the environmental and mechanical conditions are presumed to remain closely similar. Following a non-recorded run that verifies nominal system performance, data are generated in sessions that last about an hour.

Feedback during a session is based on comparison of the high and low intention runs with the baseline of the current set. This requires that the first run in all sets be the baseline, and hence only the comparison of randomly ordered high versus low runs is strictly immune to secular trends in the machine's performance. Actually, no such trends have been seen in extensive calibration tests, with the exception of some correlations with changes in atmospheric variables, and these variations are typically much too slow to have any bearing on within-set comparisons. More specifically, temperature, humidity, and barometric pressure are routinely recorded, and the calibration data indicate that barometric pressure is correlated ($r = -0.93$) with the overall change in velocity during a run. Temperature and humidity are also related, but cross-correlated with pressure, so that a regression model using only pressure can account for about 90% of the variance from these sources. Analysis software calculates a correction factor from barometric pressure readings to compensate for the influence of the environmental variables on the pendulum damping rate, but because comparisons are all made within the sets, this correction is negligible.

The computer program includes an option for delayed start of a sequence of preprogrammed runs. This is used for overnight calibrations, and also for formal experiments with the operator in a remote location. In the latter case, an arrangement is made to generate data in session-length blocks beginning at a specified time, with runs spaced at five minute intervals. The operator reports the order of the HI and LO intentions after the data have been generated and recorded, and only then receives feedback.

The experimental parameters maintained in the index and logbook include the mode of instruction and the mode of feedback. Operators may choose the order of HI and LO intentions, or have the order assigned randomly by the program. There are several options for feedback, including digital or color indicators, or both, or the operator may choose to have no explicit feedback. The digital option is a computer display of the positive or negative cumulative deviation of the present run's change in velocity in each half swing, compared with the baseline. Color feedback shows increasing positive deviations as amber, then red illumination of the pendulum bob, and negative deviations as green, changing to blue. Operators are encouraged to generate multiple series, and to explore the optional instruction and feedback modes. The planned analyses include comparison of these options as well as comparison of individual operators and the male and female subsets.

Data Processing

Extensive processing is needed to transform the original data stream into well-behaved random variates, suitable for statistical comparisons to determine operator effects. The ultimate goal is to reduce the measured data for each run to quantities that may be compared using robust parametric tests. The

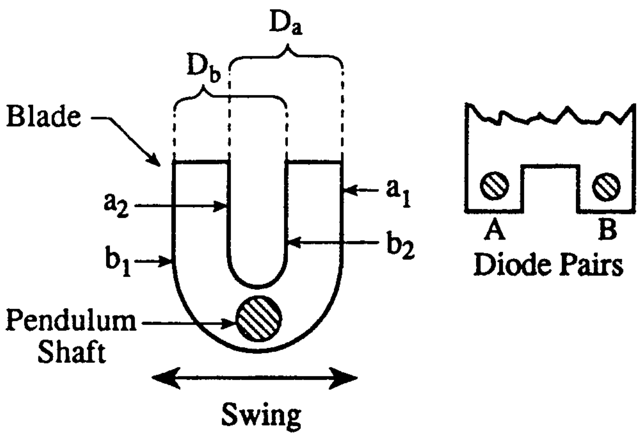

Figure 3: Photodiode Measurement System

original data are auto correlated, nonlinearly decreasing values, and are converted to normalized scores that are more nearly linear and are uncorrelated. The final comparisons are based on subtractions between nominally equivalent points in the normalized time series, compounded across the run. The resulting summary numbers are well-behaved, as described in more detail in the Calibrations section.

A complete description of the analysis including details of the normalization is provided in Nelson & Bradish, 1993. Briefly, the measurement/analysis logic proceeds as follows: Two photodiode pairs mounted at the nadir of the pendulum swing have their respective light beams interrupted by the double blade on the pendulum shaft (Figure 3). Blade edges a_1 and a_2 interrupt photodiode beam A as the pendulum swings rightward; times A_1 and A_2 are read from a 50 nanosecond resolution clock (32 bit binary counter) and recorded in computer memory. Similarly, passage of edges b_1 and b_2 over detector B on the leftward swing are recorded as times B_1 and B_2

For each such half swing, the raw data are thus two interrupt times that are recorded along with a status byte that identifies left and right swings and a checksum that validates data transmission. From these times and the distance between edges, corresponding right and left velocities, V, are calculated. For each run, an average change in velocity from swing to swing, $V_i - V_{i+1}$, is computed and normalized by the current swing velocity. For each half-swing the normalized change in velocity is:

$$\Delta V_i = \frac{V_i - V_{i+1}}{(V_i + V_{i+1})/2}$$

A grand mean for the run is computed across all half-swings, and differences of the means for the HI and LO intentions are assessed using Student t-tests; for convenience, these scores may be converted to standard Z-scores, i.e. expressed in units of the standard deviation of the mean, via the inverse normal distribution. These calculations are made for each series, and the results provided to operators as feedback. For concatenations of more than one series, analogous computations are made by compounding the individual tripolar sets without regard to their original series membership. In addition to the HI – LO comparison, an orthogonal comparison is made of the combined intentional runs vs baselines (INT – BL). For the pre-planned comparisons, a directional prediction was made, and the 0.05 criterion for "significant" deviation corresponds to a Z-score of 1.645.

Calibrations

Since theoretical modeling of ideal pendulum function provides only a rough approximation to the precise empirical measures of a complex, real system, experimental data can only be assessed against a background of calibrations that characterize the performance of the pendulum in the absence of operator interactions. For calibration runs, the computer program provides fully automatic control of the machine and permits delayed start times so that data may be taken during the night when there is little building activity and no people present, as well as during normal laboratory hours. Calibrations were done as sets of 27 runs, some taken in single sessions typically beginning at 2:00 am, and others during the day, to determine whether the activity of people in the laboratory could detectably influence pendulum performance. These two categories of calibrations are indistinguishable. To assess distribution characteristics and confirm the validity of the statistical processing, the calibration data were arbitrarily assigned to the three intention categories, then processed as if they were experimental data taken in 9-set series, with comparisons made of the "HI" and "LO", and both of these with the "BL". This random assignment procedure was used to construct 600 artificial series t-scores. A goodness-of-fit comparison of these with the appropriate theoretical Student t-score distribution yields $\chi^2 = 11.964$, based on 13 df, with a corresponding probability of 0.531. Thus, although some session-to-session changes due to atmospheric effects are detectable in the mean and standard deviation, these are normalized correctly by the within-set differential analysis.

Results

The formal experiment began on January 10, 1990; on February 1, 1993, the decision was made to conclude the global accumulation of data, and thereafter to limit data collection to the production of large individual operator databases for systematic exploration of secondary parameters. This report summarizes the primary results of a comprehensive analysis of the three-year pendulum database.

The entire formal database contains 235 complete series and 5 partial series, for a total of 1545 runs in each of the three intentions (HI, LO, and BL). The

TABLE 1
Full Database, Differences by Major Parameters
HI - LO Comparisons and INT - BL Comparisons

Subset	N-Pairs	Diff	SD	Z, HI-LO	p-value	Z-INT-BL	p-value
All Data	1545	1.767	97.5	0.713	0.238	1.367	0.086
Local	915	1.294	100.8	0.388	0.349	1.245	0.107
Remote	630	2.456	92.4	0.667	0.252	0.642	0.260
Female	770	−0.792	106.1	−0.207	(0.418)	0.650	0.258
Male	775	4.310	88.0	1.362	0.087	1.340	0.090
Volitional	421	−7.470	101.9	−1.502	(0.067)	1.207	0.114
Instructed	494	8.762	99.5	1.953	0.025	0.572	0.284
Full Feedback	666	5.004	97.4	1.325	0.093	0.993	0.160
Other Feedback	249	−8.630	109.2	−1.244	(0.107)	0.751	0.226
Female Local	609	−3.448	106.4	−0.799	(0.212)	0.664	0.253
Male Local	306	10.730	88.2	2.118	0.017	1.353	0.088
Remote Female	161	9.256	104.9	1.116	0.132	0.136	0.446
Remote Male	469	0.121	87.7	0.030	0.488	0.682	0.248
Female Volit.	313	−9.520	109.1	−1.540	(0.062)	1.054	0.146
Male Volit.	108	−1.528	77.5	−0.205	(0.419)	0.592	0.277
Female Instr	296	2.973	103.2	0.495	0.310	−0.128	(0.449)
Male Instr	198	17.416	93.1	2.606	0.005	1.238	0.108
Full Fbk Fem	377	1.765	103.6	0.331	0.370	0.317	0.376
Full Fbk Male	289	9.229	88.6	1.764	0.039	1.262	0.104
Other Fbk Fem	232	−11.918	110.5	−1.636	(0.051)	0.656	0.256
Other Fbk Male	17	36.244	79.5	1.760	0.039	0.522	0.301
Color Fbk	144	−0.088	81.9	−0.013	(0.495)	0.486	0.313
Digital Fbk	27	−19.753	213.9	−0.474	(0.318)	−0.507	(0.306)
No Fbk	78	−20.550	101.0	−1.773	(0.038)	1.563	0.059

incomplete series, concatenated as sets of runs, are included in the analyses since they are viable data in all other aspects of protocol. One or more series were completed by 42 operators, 21 female and 21 male. Of these, 40 operators generated at least one local series, and 12 operators, including the two who were unable to produce local databases, completed one or more series from remote locations.

Full Database

The database can be separated into several subsets taken under different conditions. There are 915 local and 630 remote runs, and an approximately equal number of runs by male and female operators (775 and 770, respectively). Comparisons can also be made between the volitional and randomly instructed modes for assignment of intention, and between different feedback modalities. Table 1 summarizes the results for the complete database broken down by location, sex, type-of-instruction, and type of feedback. The feedback comparison is between "full" (color plus digital) vs "other" (digital alone, color alone, or none). These subsets are further subdivided into male and female subsets for location, type-of-instruction, and feedback modality. The table shows the number of pairs (N-pairs), their mean difference (Diff), the

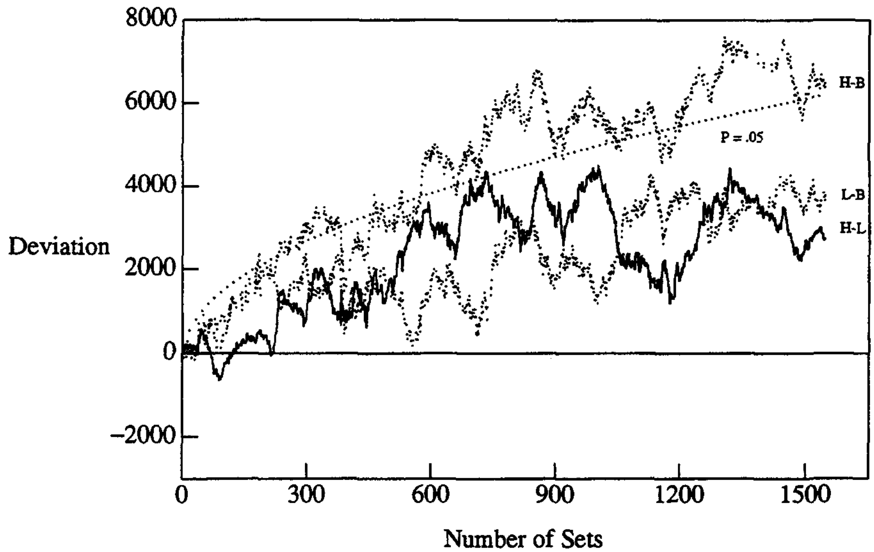

Figure 4: Cumulative Deviation of Intentions (All Data)

standard deviation of the distribution of differences (SD), and the Z-score for the mean difference, with corresponding p-value. Z-score equivalents to the original calculated t-scores are used for convenience in making comparisons; only the Z-score and the p-value are given for INT – BL.

The overall difference of HI – LO is positive, but non-significant. Several subsets exhibit significant differences, notably the Instructed, the Male Local, the Male Instructed, and the Male Full-feedback groups. The Volitional vs Instructed difference appears to be very important in this database, yielding opposite effects and a computed Z-score for the difference of 2.443. The Male vs Female difference is quite large in the local data, with a difference Z of 2.063. This difference is reversed, though not as strong, in the Remote subset; however, the reversal is heavily influenced by the large database from operator 144, as discussed in the Remote Data section. There is also a strong difference between full feedback, which yields a positive effect, and the other three feedback options, all of which show null or negative results (difference $Z = 1.817$).

A graphical representation of the data in the form of cumulative deviations from the theoretical chance expectation displays the chronological development of the statistical trends. The terminal value of such a cumulative deviation corresponds to the mean difference of the data distribution (multiplied by the number of trials). The full database concatenation shown in Figure 4 resembles one-dimensional random walks with steps away from the expected mean in the positive or negative direction. To scale the deviation, the figure includes a dotted curve showing the locus of the 0.05 p-value for cumulative deviations, based on the standard deviation of the HI – LO differences.

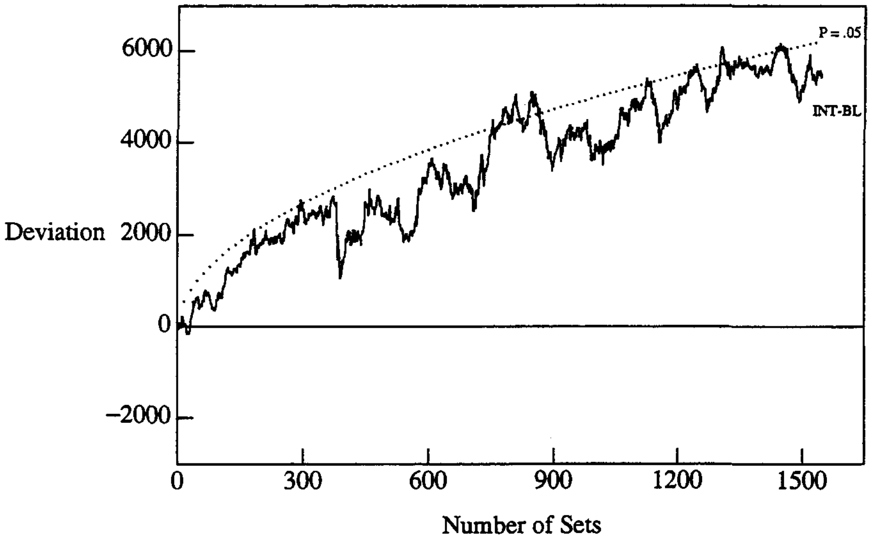

Figure 5: Average Intention vs Baseline (All Data)

The somewhat irregular accumulation of HI – LO deviations in the direction of intention is shown as a solid trace, which approaches significance in the early part of the database, but retreats somewhat during the later portion. The dotted traces showing the other two comparisons display the striking asymmetry mentioned earlier, in that the differences of HI vs BL tend to be consistently positive and correlated with intention, while the corresponding LO vs BL differences actually tend toward a positive deviation, opposite to intention.

This strong asymmetry of performance contributes heavily to the non-significant overall result, despite the unusual proportion of extreme scores. For 22 operators, both the HI and the LO intention scores are higher than the baselines, significantly so for five individuals, and the scores compound to a positive overall INT – BL difference that approaches significance. All but two of the subset differences are positive, i.e. the intentional runs tend to be higher (show smaller damping rates) than the baseline runs. Figure 5 shows this asymmetry to be a consistent difference between the combined average intention and the baseline data that accumulates steadily over the full database.

Although no prediction was made for such asymmetry, the figure again includes the one-tailed $p = 0.05$ envelope to provide a sense of scale. These strong INT – BL results indicate a differential effect of operator intention compared with baselines that is orthogonal to, and hence independent of, that predicted in the primary hypothesis addressing the HI – LO difference.

The question arises whether the asymmetry might reflect a consistent trend within the sessions, where the baseline, as the first member of each set, might typically be lower than the intentional runs for prosaic reasons such as changes in temperature or other environmental variables. To address this concern, the

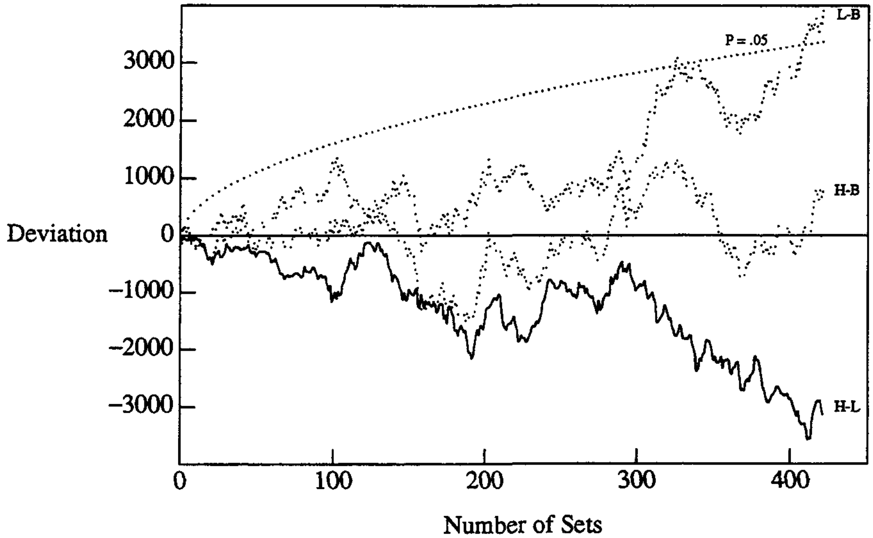

Figure 6: Cumulative Deviation of Intentions (Volitional Data)

BL data within sessions were compared. No significant differences were found in the aggregated baselines from the first set compared with the second or third set, and the distribution of the signs of the differences was well within chance expectations based on the appropriate binomial. In fact, between the first and second aggregate BL there is a small positive difference, the opposite direction from that required to explain the asymmetry in the intentional data.

Local Data

Five of the 40 local operators (12.5%) show independently significant HI – LO differences in the direction of intention. However, as noted earlier, other individuals produced comparably strong effects in the direction opposite to intention. Examination of the distribution of operators' Z-scores reveals that the large number of extreme scores in both tails leads to a standard deviation of 1.255, a significant increase over the theoretical expectation ($p = 0.011$), indicating that individual operator differences may be important in this database. Contributing to the variance increase, males have a significant positive achievement ($p = 0.017$), while the female operators' HI – LO difference is negative. This male-female difference obtains over both modes of instruction and over both categories of feedback.

The most prominent difference among subsets of the pendulum database is that between volitional and randomly instructed runs. Figures 6 and 7 show that both have steady accumulations, but in opposite directions. This difference is more pronounced in data from male operators alone, and the Instructed subset for the male operators exhibits by far the largest deviation in the entire database, with a p-value of 0.005 for the HI – LO difference.

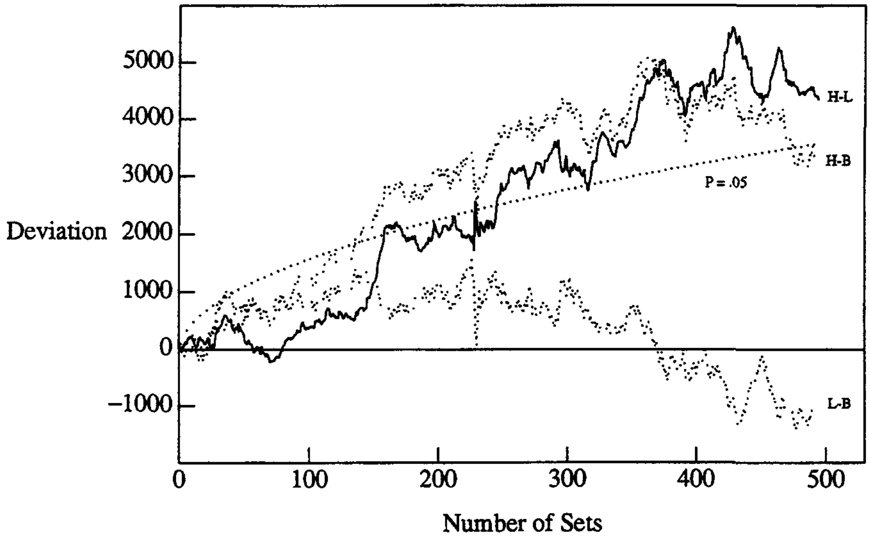

Figure 7: Cumulative Deviation of Intentions (Instructed Data)

Remote Data

Under the remote protocol, 630 runs were generated by 12 operators. In the HI – LO comparison, only one of the 12 achieved a significant deviation, but eight had a positive effect. This subset is severely unbalanced by one operator (144) who comprises nearly half the total database, exhibiting a consistent though non-significant negative yield. This contribution severely depresses the overall remote effect size, although it remains larger than that of the local runs. The combined results of the 11 other operators, in contrast, are positive and significant ($p = 0.048$), and significantly different from those of operator 144 ($p = 0.027$). Figure 8 shows the remote data in the cumulative deviation format, and displays its chronological development.

Two long negative trends are apparent (approximately sets 175 - 325 and 425 - 575), composed primarily of data from operator 144, which are shown separately in Figure 9. If these data are not included, the early trend continues and the remote database shows a significant HI – LO difference ($Z = 1.667$), with an effect size considerably larger than that of the local database. This subset of all remotes excluding operator 144 is shown in Figure 10.

The remote data are important for both practical and theoretical reasons. The potential vulnerability of the pendulum to operator induced mechanical disturbances is totally obviated for the remote data, which thus provide a protected subset immune to spurious influences that might conceivably affect local data. Beyond this, the appearance of effects with operators located up to thousands of miles from the device has major implications for modeling the anomalous correlations, especially if the effect size is commensurate with that

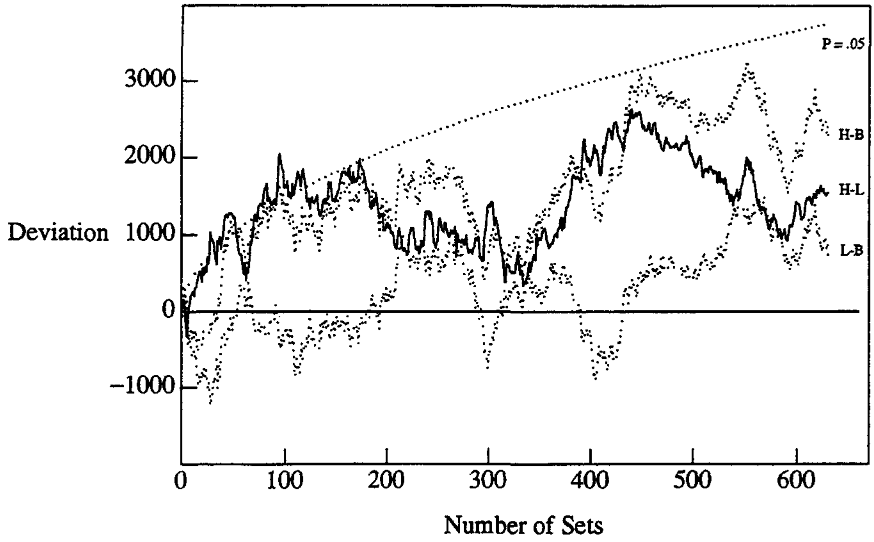

Figure 8: Cumulative Deviation of Intentions (Remote Data)

in local experiments. In fact, although the difference is not significant, the remote effects are larger than those found in the local data. It is also worth noting that the pattern of results for the orthogonal INT – BL comparison resembles that of the local data, with a net positive trend.

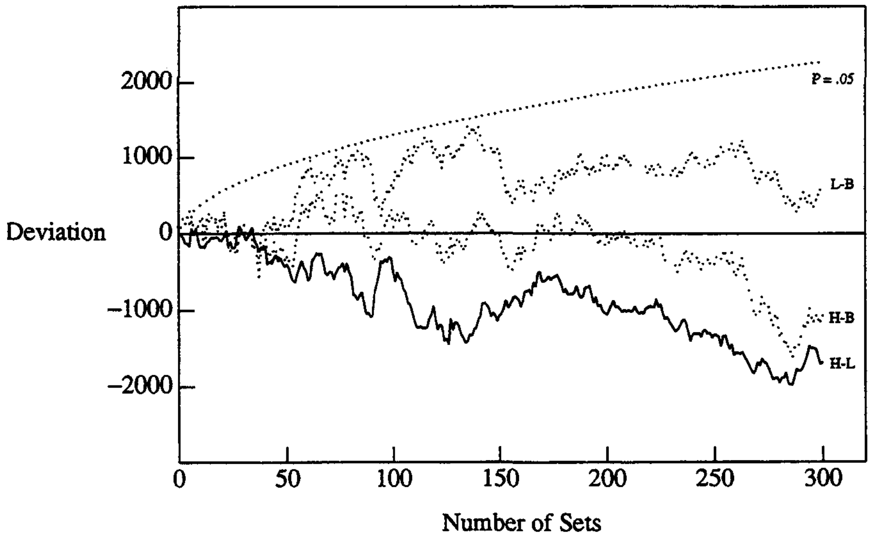

Figure 9: Cumulative Deviation of Intentions (Operator 144)

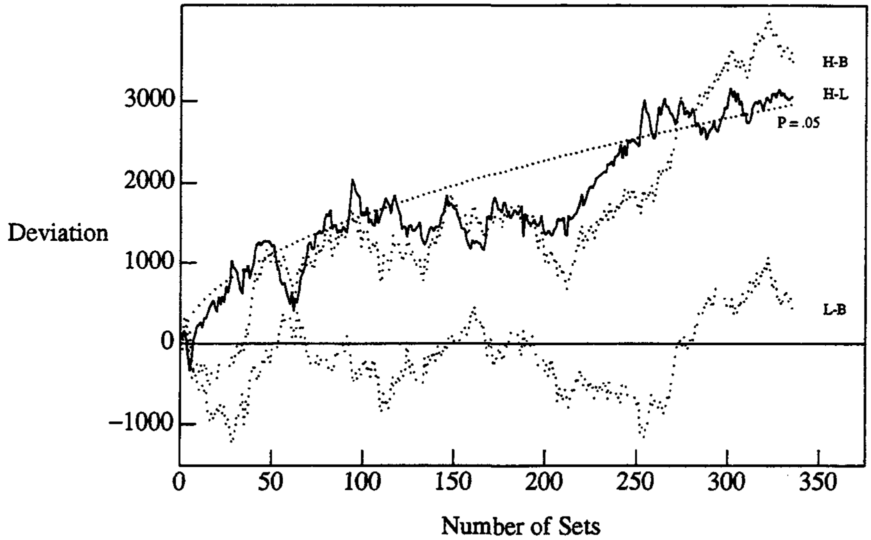

Figure 10: Cumulative Deviation, Remotes (Excluding Operator 144)

ANOVA and Database Structure

The pendulum database has several potentially important factors that may interact with the primary variable of operator intention, and a more rigorous assessment of their independent contributions requires a comprehensive analysis of variance. The experiment is formally a factorial design, with unequal cell populations and some empty cells. While all interactions cannot be calculated, an unbalanced multi-factor analysis of variance can be performed, yielding a model that provides a useful overview and background for the individual t-test assessments of particular questions. To avoid small cell populations, the ANOVA was restricted to 200 series produced by "prolific" operators who have completed 25 or more sets of runs. Eighteen people have met or exceeded this criterion, and they have collectively produced a total of 1311 tripolar sets of runs (85% of the full database) in the local and remote protocols. The results in this prolific operator database are consistent with those of the full database (Nelson and Bradish, 1993).

Table 2 displays the ANOVA results, showing the main effects and the independent contributions from secondary parameters and their two-way interactions, using the HI – LO Z-scores for the series as the dependent variable. For each potential source of variance, the table gives the sum of squares, the degrees of freedom (D. F.), the mean square, and the F-ratio with its associated p-value. The residual variance is used as the error estimate for all factors.

Combined contributions from the main effects indicate the degree of overall structure in the model, i.e. a relationship of the HI – LO difference to the experimental parameters, and the remaining rows in the table show the specific

TABLE 2
Pendulum ANOVA, Prolific Operator Database

Source	Sum of Sqrs	DF	Mean Sqr	F-Ratio	p-value
Main Effects	11.947	4	2.987	2.845	0.025
R/V/I	7.697	2	3.849	3.666	0.027
M/F	0.468	1	0.468	0.446	0.512
F/O	3.782	1	3.782	3.602	0.059
Interactions	2.469	5	0.494	0.470	0.798
R/V/I/xM/F	1.126	2	0.563	0.536	0.586
R/V/I/xF/O	1.237	2	0.618	0.589	0.556
M/F/xF/O	0.105	1	0.105	0.100	0.755
Covariate	1.371	1	1.271	1.206	0.255
Residual	198.427	189	1.050		
Total	214.214	199			

contributions from these parameters and their interactions. The secondary parameters include a factor comparing three distinct instruction protocols, i.e. the remote subset and the volitional and randomly instructed local subsets (R/V/I); a two level factor for male and female operators (M/F); and a two level distinction of full feedback (both color and digital) vs all other feedback options (F/O). It should be noted that the remote subset does not include data from the V/I subset nor the F/O factor, and hence the R/V/I x F/O interaction is not influenced by the remote data. The INT – BL difference is entered as a covariate in the primary calculation to test its orthogonality. A significant contribution would indicate that this difference is not independent, but covaries with one or more factors in the model. In accord with the expected orthogonality, it is found to yield a negligible contribution.

Confirming the earlier a*d hoc* results, the ANOVA model returns a p-value of 0.025 for the main effects, providing a clear indication of structure in the database, driven by a significant contribution from differences among the volitional, instructed, and remote subsets, and by a strong difference of the combined color/digital feedback subset compared with all other feedback modes. The former contribution is primarily from a difference between the two instruction modes, which yield opposite effects; a supplementary model restricted to local data alone shows the V/I factor to be significant at $p = 0.014$. These two conditions effectively cancel each other in the full database and this largely explains the small size of the overall deviation attributable to operator intention (see also Table 1).

The difference between Volitional and Instructed assignment of intention is striking, and broadly distributed across operators, both in the magnitude of the HI – LO difference and in the degree of asymmetry reflected in the INT – BL comparison, but the present analysis does not suggest an adequate explanation for the V/I difference. Certainly the significant asymmetry of the Volitional subset contributes to this difference, but it does not by itself explain the negative sign of the Volitional data. One possibility is that certain consistently successful or particularly unsuccessful operators tend to select just one of the two modes, and, in fact, operators do express strong preferences and tend to use only one of the modes. However, an examination of individual databases does not support this hypothesis. Of the prolific operators who did explore both modes, about 75% succeeded in the Instructed protocol, but only about 30% did so in the Volitional mode.

The feedback comparison collapses three infrequently used modes, color only, digital only, and no feedback, into a single category for comparison with "full" feedback combining both color and digital modes, which operators chose almost three times as often as the other conditions combined (see Table 1). Separately, each of the three less frequently chosen feedback modes yields a negative net effect, and in this ANOVA model, the F/O factor indicates a marginally significant difference of these compared with the full feedback.

The male vs female factor is not a large contributor, nor are its interactions with R/V/I or F/O. This appears to be inconsistent with the *t*-test comparisons which suggested a difference in male and female performance. A separate model that collapses the volitional and instructed datasets (making a local subset for comparison with the remotes) shows a relatively strong, though non-significant interaction of the M/F factor with the new "location" factor. That is, the males tend to do better in the local condition, and females better under the remote protocol. Another separate model was computed replacing the M/F factor with an 18 level factor representing Operators. It showed that differences among the prolific operators do not generate a significant contribution to the model, despite the increased variance across all 40 operators' results discussed in section 6.2, suggesting that the other experimental factors account for some part of the apparent inter-operator variability.

Discussion and Conclusions

In designing this experiment, one of the primary questions to be addressed was whether an analog measurement of variations in the performance of a physical system, together with the "analog" character of the operator's experience, might reveal larger effects of human consciousness than those shown earlier in digital systems. That question has been answered in the negative. While the analog linear pendulum appears to be viable as a formal experiment for exploration of interactions of human consciousness with physical systems, it does not yield stronger results than the digital experiments. Indeed, the character of the results in the pendulum experiment closely replicates those in both our REG and RMC studies. Again there is a persistent accumulation of very small statistical deviations in the direction of intention, contributed by many of the operators rather than by one or two particular individuals, and again there is evidence of an asymmetry between the two intentions. This marginally significant asymmetry is independent evidence of an effect of human intention, and it bears further examination to explore its correlates. For example, the effect is particularly strong in the volitional subset, as is true for the HI –

LO difference as well, and it is stronger for the male operators than the female. Virtually all the effect derives from trends opposite to intention under the LO instruction, that is, there is an asymmetry within the asymmetry that favors the HI direction. It is instructive that similar asymmetries have been observed in the benchmark REG experiment, and with particular clarity in the RMC experiment (Nelson, et al, 1991; Dunne, Nelson, & Jahn, 1988).

The remote database also shows a larger effect size than the local database, as was found in both the REG and RMC experiments (Dunne and Jahn, 1991). A direct comparison of effect sizes across experiments based on the number of trials or bits processed is not feasible since the analog and binary event measures are fundamentally different. However, the time spent by operators interacting with the experiment can be used to normalize the terminal scores of these experiments in a way that allows a tentative comparison (Nelson, 1994). For the pendulum experiment, the combined local and remote effect size $E(t) = Z\sqrt{\text{hrs}}$ calculated for the prolific operator subset is 0.170. The corresponding prolific operator effect sizes for the diode-based REG and the RMC are 0.236 and 0.251, respectively, both well within chance variation of the pendulum effect size.

This comparability of outcomes also has an implication for the integrity of the pendulum data. Since complete isolation from possible spurious influences is impractical, the experiment depends on a physical and statistical design that allows confidence in the data without making the experiment cumbersome. The similarity of the pendulum results to those of the fully protected REG, along with the comparability of the remote results, indicates that no large contributions have arisen from spurious sources.

A number of findings in the pendulum analysis are especially revealing in their similarities to those of other experiments. Most important is the indication of structure imposed by operator intention on a nominally random process, despite non-significant overall correlation with the damping rate. The greatest contribution to this outcome is the significant difference between randomly and volitionally instructed datasets. The magnitude of this difference and its generality across operators are unusually pronounced in the pendulum experiment, and future experiments might profitably focus on this parameter. It is important to note that the random instruction provides full assurance that the HI and LO intentions cannot be chosen to exploit any temporal trends, yet this condition yields the strongest, indeed independently significant, results. The instructed data show less of the asymmetry that characterizes the overall database, helping lay to rest any concern that the asymmetry might reflect some unknown, non-anomalous aspect of the experimental protocol. Indeed, it can be seen that the largest portion of the asymmetry is due to the strongly inverted LO – BL data within the volitional subset.

Of the four feedback options, by far the most successful is the combined color and digital feedback. It is also greatly preferred by the operators over other options. Color alone has a fairly substantial database, while the digital and no-feedback subsets are very small, but none of these alone appears to promote successful performance. It must be noted that assessments in the small datasets are vulnerable to confounding, since the data represent only two or three operators, and there is modest evidence for inter-operator differences. It should also be noted that the remote data, which show a larger effect size than the local data, have no on-line feedback at all, lending a further cautionary note for interpreting apparent differential effects of feedback conditions.

Although most operators regard the pendulum as an attractive and enjoyable experiment, its relatively modest yield in terms of effect size, its cumbersome data processing, and its potential vulnerability to various non-anomalous influences will probably limit future data collection to explorations by individuals who wish to develop large personal databases. These data will be used to determine more precisely the differential effects of optional parameters, differences among operators, and differences between local and remote protocols.

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References

Dunne, B. J., Nelson, R. D., and Jahn, R. G. (1988). Operator-related anomalies in a random mechanical cascade experiment. *Journal of Scientific Exploration,* 2, 155.

Dunne, B. J. and Jahn, R. G. (1991). Experiments in remote human/machine interaction. *Journal of Scientific Exploration*, 6, 311.

Jahn, R. G., Dunne, B. J., and Nelson, R. D. (1987). Engineering anomalies research. *Journal of Scientific Exploration*, 1, 21.

Nelson, R. D., Dunne, B. J., and Jahn, R. G. (1984). *An REG Experiment with Large Data Base Capability, III: Operator Related Anomalies* (Technical Note PEAR 84003). Princeton Engineering Anomalies Research, Princeton University, School of Engineering/Applied Science.

Nelson, R. D., Dobyns, Y. H., Dunne, B. J., and Jahn, R. G. (1991). Analysis of *Variance of REG Experiments: Operator Intention, Secondary Parameters, Database Structure* (Technical Note PEAR 91004). Princeton Engineering Anomalies Research, Princeton University, School of Engineering/Applied Science.

Nelson, R. D. and Bradish G. J. (1993). *A Linear Pendulum Experiment: Effects of Operator Intention on Damping Rate* (Technical Note PEAR 93003). Princeton Engineering Anomalies Research, Princeton University, School of Engineering/Applied Science. An earlier version was presented at the 11th Annual Convention of the Society for Scientific Exploration, Princeton NJ, June, 1992.

Nelson, R. D. (1994). *Effect Size per Hour: A Natural Unit for Interpreting Anomalies Experiments* (Technical Note PEAR 94003). Princeton Engineering Anomalies Research, Princeton University, School of Engineering/Applied Science.