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RESEARCH

Exploratory Evidence for Correlations Between Entrained Mental Coherence and Random Physical Systems

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Abstract—An experiment tested whether mental coherence entrained in groups would affect sequences of data generated by truly random number generators (RNGs) in the vicinity of those groups. Coherence was entrained by having groups listen to a prescribed series of binaural beat rhythms during a 6-day workshop. Two RNGs based on electronic noise and one on radioactive decay latencies were located in the building where the workshops took place. Random data were continually collected from these RNGs during 14 workshops. As controls, the same RNGs generated data in the same locations and times but during 8 weeks when no workshops took place. Other RNGs in two distant locations were run as additional controls.

An exploratory hypothesis predicted that fluctuations in entrained mental coherence associated with the workshop activities would modulate the random data recorded during the workshops. This was predicted to result in positive correlations between random data streams collected from one workshop to the next. Results showed that during the workshops the overall correlation was positive, as predicted ($p = .008$); during control periods the same RNGs produced chance results ($p = .74$). Random data generated in distant locations also produced results consistent with chance.

Keywords: field consciousness—random number generator—RNG—mind-matter interaction

Introduction

Field consciousness experiments study a hypothesized mind-matter interaction (MMI) effect associated with the presence of "mental coherence" in groups (Nelson et al., 1996, 1998; Radin, 1997, 2006). This idea refers to a felt sense when individual thoughts and actions seem to merge into a single group thought or action. A qualitative sense of coherence or "flow" is often reported during meaningful religious rituals, emotionally stirring speeches, and team sports

(Csikszentmihalyi, 1990, 1997). At such times the attention of the participants seemingly locks onto the "same wavelength" and individuals often report a subjective shift.

The MMI hypothesis proposes that such felt shifts are associated with physical changes in the local environment, i.e., that when the "mind" side of a postulated MMI relationship becomes unusually coherent or ordered, then the "matter" side also becomes more coherent or orderly. This idea predicts that if mental coherence fluctuates from high to low according to a prescribed plan, and that sequence of fluctuations is repeated, say, *N* times, then random data streams continuously recorded during those *N* periods ought to positively correlate with each other because they should have been modulated by mind in approximately the same way. This prediction was tested in the present experiment.

To detect the proposed effect, measurements of a suitable physical system are required. Truly random number generators (RNGs) have been used for this purpose because they are physical systems designed to produce maximum entropy, and as such, if negentropic or unexpected periods of order appear, they can be detected in a straightforward statistical manner. In random samples of, say, 200 successive bits, order is postulated to appear either as more 0s or more 1s than one would expect by chance. The statistic most often used to measure this type of order is a shift in sample variance rather than a shift in the mean, because an excess of either 0s or 1s represents forms of statistical order. Note that "variance" here refers to the distribution of samples, and not to how bits are distributed within samples. That is, the MMI hypothesis predicts that, say, a histogram created out of samples of 200 random bits each, which would ordinarily resemble a binominal distribution, would instead have too many samples in the tails of that distribution. It is the variance of such a distribution that is predicted to be larger than expected by theoretical chance, or as compared to the variance of an empirical control distribution, when modulated by coherent mind.

Previous field consciousness experiments have yet to be evaluated via formal meta-analysis, but the preponderance of evidence provided by previous studies seems to support the existence of an MMI effect. Variation in outcomes across studies is undoubtedly due to differences among groups, contexts, and environments, but some of that variance is also due to uncertainties involved in inferring if and when mental coherence arises.

One purpose of the present experiment was to explore whether a more reliable MMI effect could be obtained if mental coherence was specifically generated, rather than inferred by context or subjective reports. The coherence-stimulating technique used in this study involved the use of binaural-beat audio tones known as Hemi-Sync®. The term "binaural-beat" refers to a method in which one tone at, say, 400 Hz is played in one ear while another tone at, say, 406 Hz is played in the other ear. These two pure tones are heard along with a subjective beat frequency, or warbling tone, generated by overlapping circuits in the brain's audio cortex (Atwater, 2001; Kuwada et al., 1979; Lane et al., 1998; Oster, 1973).

The beat frequency acts to entrain the brain's endogenous rhythms; in this example the binaural-beat would tend to promote a theta rhythm at 6 Hz. Hemi-Sync® audio programs combine this binaural-beat technique with standard relaxation techniques, including reduced environmental stimulation, controlled breathing, guided affirmations and visualization. The audio programs are offered in varieties designed to promote relaxation, meditation, creativity, etc., as well as to facilitate exploration of expanded states of consciousness (Atwater, 1997).

During the 6-day workshops known as the Gateway Voyage®, developed by The Monroe Institute, groups of 20 to 25 people simultaneously listen to a prescribed sequence of Hemi-Sync® programs presented over headphones,[1] with each person in a private listening chamber. We anticipated that these group entrainment periods would generate periods of collective mental coherence, similar to the "group mind" evoked by participating in a drumming ceremony. After listening to a Hemi-Sync® program for about 45 minutes, Gateway Voyage® groups reassemble and discuss their experiences. This listening-discussing cycle is repeated throughout the day for up to 6 hours a day, and each day of the workshop follows a planned schedule for audio programs, breaks, meals, etc.

A second purpose of this experiment was to explore an implication of the MMI hypothesis, namely that fluctuations in group coherence ought to be correlated with fluctuations in randomness. The Gateway Voyage program was particularly useful in testing this idea because the workshops always began at the same time on the first day, and then presented the same sequence of Hemi-Sync® audio programs at the same time of day, over the next 6 days. If group coherence increased while listening to the programs and declined during breaks, meals and while sleeping, then similar variations should appear in the random data from one workshop to the next. To test this idea, all cross-correlations between random data collected in repeated workshops were calculated, and we predicted that overall the grand cross-correlation would be positive. By contrast, data collected from the same RNGs in the same locations, starting at the same time and also running continuously for 6 days, but with no workshops taking place, were predicted to not show any systematic cross-correlations.

This design was conceptually similar to a previous correlational study by Radin (1997: 168), which examined fluctuations in group coherence associated with the inferred mental focus of tens of millions of television viewers watching programs on the four major television channels during an ordinary evening broadcast, versus the outputs of three independent RNGs. That study predicted, and found, a positive correlation ($p < .01$).

It should be noted that the correlation analysis reported here was not preplanned. This analysis was devised in response to referees' comments on an earlier draft of this article. The original analysis followed procedures used in previously reported field consciousness studies, namely to examine shifts in sample variance. Because we planned to collect massive amounts of data, which in turn would provide exceptional statistical power, we knew that if the RNG outputs showed even miniscule deviations from theoretical expectation, then we might end up with strong, but spurious, statistical outcomes. So we planned to use the data collected during control weeks to allow for statistics based on empirical means and standard deviations rather than theoretical expectations. The results of that analysis for all RNGs collected near the workshop was a deviation in sample variance associated with a combined Stouffer $Z = 3.17$ ($p = .0007$, one-tailed). For RNGs generating data at the same time, but in locations distant from the workshop, the results were associated with Stouffer $Z = -3.10$ ($p = .002$, two-tailed, as no directional prediction was made for the remote RNGs). The results for RNGs located at the workshop were heavily influenced by the outcome of the Geiger-counter–based RNG, which resulted in $z = 4.45$ ($p = .000004$). The referees felt that the strong deviation observed in an RNG not previously vetted in field-consciousness studies, combined with unexpectedly strong *negative* results in the remote RNGs, cast the experimental outcome in doubt. In response to such comments, we developed an alternative (and thus post hoc) analytical way to test the MMI hypothesis without relying on deviations from chance expectation in individual RNG outputs.

Methods

Design

RNGs generate sequences of truly random bits, 0s and 1s, that are independent and identically distributed with $p_0 = p_1 = .5$. The two electronic RNGs employed in this experiment had been used extensively in previous MMI research.[2,3] The third, a Geiger-counter–based RNG, had also been used in a field consciousness experiment (Radin et al., 2004).

Randomness in one electronic RNG, the Mindsong, was based on electronic noise in a field effect transistor. In the Orion RNG randomness was based on quantum tunneling effects in two independent analog Zener diodes. The Aware Electronics RM-60 randomness comes from unpredictable latencies associated with emission of radioactive particles.[4] In this experiment, the source of such particles was thorium from a Coleman lantern mantel. All of these devices generate sequences of truly random bits by accessing the fastest moving bit in a clock when a random event is detected. Because computer CPU clocks today commonly run at GHz rates, and random events are generated at much slower rates (typically 10 KHz or less), samples of random bits produced by these devices conform closely to theoretical expectation. The outputs of both the Orion and the RM-60 have passed Marsaglia's "Diehard" suite of tests, which is one of the gold-standard tests for randomness.[5] The Mindsong produces distributions of bits with a mean value close to theoretical expectation, but with a slightly elevated sample variance.[6]

All of the Gateway Voyage® workshops took place in the Nancy Penn Center (NPC) at The Monroe Institute. During a few workshops we ran just the Mindsong RNG, in others we ran just the Orion, and in still others we ran all three

RNGs simultaneously. We also ran RNGs in two distant locations while the workshops were underway. One was located in a laboratory about a tenth of a mile from the NPC, and the other was located about a mile away in a building called the Roberts Mountain Retreat (RMR). The distant RNGs were in quiet locations away from human activity and the workshop participants did not know of their existence. A few members of the workshops did know that one or more RNGs were running in the NPC location, but it was hidden and no feedback was provided about its output either during or after the workshop. To provide control data, the same RNGs were also run continuously during weeks when no workshops were taking place.

Data from the electronic RNGs were acquired using custom Windows-based software that recorded all generated bits.[7] This included 7600 bits per second from the Orion and 2600 bits per second from the Mindsong. Data from the RM-60 RNG were acquired using Windows-based software provided by Aware Electronics.[8]

Participants

Each workshop consisted of about 20 men and women with an average age of 48 years (range, 16–77 years). Approximately 52% of participants were male, 78% were from the USA and Canada, and the others were mostly from Europe. A wide range of professions were represented; 92% had at least some college education.

Analysis

The basic datum was the *sample,* defined as 200 contiguous random bits. All non-overlapping samples generated by each RNG were used in this analysis. In the case of the Mindsong and Orion, both devices were connected to a computer via a serial port and bits were generated at predictable times according to a fixed baud rate.[9] In the case of the RM-60, bits were generated depending on when radiation hits were recorded, and so samples were not stored at a predictable rate.

Regardless of source, each 200-bit sample was first transformed into a standard z score as $z = (x - \mu)/\sigma$, where x was the sum of 1s in the 200-bit sample, μ was the theoretical mean (100), and σ was the theoretical standard deviation $\sqrt{50}$. Each z score was squared, and then the sum of 60 successive z^2 values was calculated, representing all bits collected in 1 minute of data collection for the Mindsong and Orion. In the case of the RM-60, the sum of 300 successive z^2 scores was calculated, representing roughly 2 minutes of data collection. These sums, which were chi-square distributed, were transformed back into a z score as $x = \sqrt{2z^2} - \sqrt{2df - 1}$ (Guilford & Fruchter, 1973: 517), where df refers to degrees of freedom, which was the number of summed z^2 scores.[10] These final z scores are convenient measures of sample variance. If z is positive it means the distribution of samples is wider than expected by chance, and if negative the distribution is thinner.

The MMI hypothesis predicts that the cross-correlations of these z scores from one workshop to the next would be significantly positive for the RNGs located in the NPC during the workshops. The same analytical procedure applied to the same RNGs run during weeks when no workshops were taking place should be consistent with chance. If the field consciousness effect extended to distant locations, then a positive correlation might also appear among RNGs running at a distance from the workshop, and no such correlation should appear when no workshops were taking place.

A Microsoft Visual Basic 6.0 program was used to reduce the raw binary data from the two electronic RNGs into 1-minute z_χ values and approximately 2-minute z_χ samples from the RM-60 data. Those data were then analyzed in Matlab (v. R2007) using a randomized permutation analysis based on the following steps:

a. Data from the electronic RNGs were formed into a matrix, M_e, in which the rows were the z_χ samples and the columns corresponded to data from separate workshops. A similar matrix, M_r, was formed for the radiation-based RNGs.
b. All correlations between unique pairs of columns were calculated. With N_c columns in a given matrix, this resulted in ½$(N_c^2 - Nc)$ correlations for each matrix.
c. The number of cross-correlations greater than zero was determined separately for the electronic RNGs and the radiation RNGs, and then summed (call this n). This simple, nonparametric measure was used to avoid any assumptions about the distribution of the cross-correlations.
d. The order of samples in each column in M_e and M_r was randomly scrambled.
e. Steps b through d were repeated 10,000 times to build up a distribution of possible values for n (call these permuted values n_r). The number of times that $n > n_r$ was counted (call this number *count*).
f. The p-value used to test the hypothesis was then p = count/10,000. The hypothesis predicted that p would be significant for RNG data collected during the workshops and consistent with chance for data collected by the same RNGs when no workshops were taking place.

Results

Between April 2003 and December 2006, experimental data were collected in one to three RNGs run simultaneously during 14 separate workshops. The same RNGs were run during 8 weeks when no workshops were taking place to provide control data, and additional RNGs were run in two distant locations during both workshops and in control periods. All together, this resulted in a total of 100 six-day experimental and control recording sessions, during which some 143 billion random bits were collected. Data collected are summarized in Table 1.

TABLE 1

Summary of Data Collected in the Experiment in the Various Locations and Conditions

	Nancy Penn Center Mindsong	Nancy Penn Center Orion	Nancy Penn Center RM-60	Laboratory RM-60	Laboratory Mindsong	Roberts Mountain Retreat Mindsong
Weeks control data	6	6	7	6	7	8
Weeks experimental data	14	8	7	7	11	13
Trials = samples/minute	789	2284	300	300	789	789
Bits/second	2630	7613	545	584	2630	2630
Bits/sample	200	200	200	200	200	200
Bits/trial	157,800	456,780	60,000	60,000	157,800	157,800
Control trials	51,798	60,461	32,984	26,974	60,438	69,120
Experimental trials	120,862	60,461	32,984	35,336	94,974	112,320
Total control bits	8.2 billion	27.6 billion	1.98 billion	1.62 billion	9.5 billion	10.9 billion
Total experimental bits	19.1 billion	27.6 billion	1.98 billion	2.12 billion	14.9 billion	17.7 billion

Note: For the RM-60 radiation-based RNG the bit rate was not fixed, and so rather than a trial defined as a specified number of samples per minute, it was defined as a fixed number of samples (300).

There were 22 data sets of electronic RNG data collected in the NPC and 7 data sets of radiation-based RNG data. Together this resulted in $462 + 42 = 504$ cross-correlations. By chance we would expect to find $504/2 = 252$ positive correlations; the mean number determined by the permutation analysis was 251.96 (see Figure 1). The observed number of positive correlations was 290; this was exceeded 80 times in 10,000 permutations, so $p = .008$. The same analytical approach was then applied to the same RNGs in the same locations, but during weeks when no workshops were taking place. In this case there were 174 cross-correlations, the mean number of positive correlations was expected by chance to be 87, and the permuted mean was found to be 87.08. The observed number of positive correlations in the actual data was 80, and the permutation-based p-value was $p = .74$.

Data collected in the distant RNGs resulted in outcomes consistent with chance. During the workshops in the laboratory location the permutation-determined p-value, combined across electronic and radiation-based RNGs, was $p = .93$ (one-tailed), and during no-workshop control periods, $p = .65$. For the RNG in the RMR location, during the workshop $p = .36$ and during the control periods, $p = .42$.

Discussion

In accordance with the field consciousness hypothesis, random data generated by three RNGs run during workshops and in proximity to the participants showed significant cross-correlations across multiple workshops. Data generated by the same RNGs run at distant locations and at different times did not.

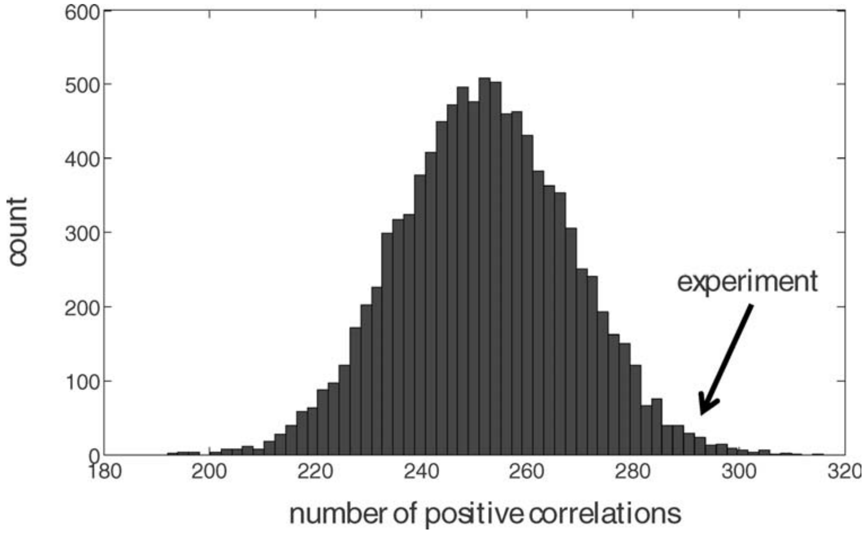

Fig. 1. Distribution of the number (of 504 possible) of positive cross-correlations in RNG outputs based on 10,000 randomized permutations of the original random data. The arrow points to the number of positive cross-correlations observed in data recorded in the actual experiment. This indicates that the RNG data streams collected during the workshops, and in proximity to the participants, tended to be more similar to one another than would be expected by chance ($p = .008$, one-tailed).

Environmental Influences

Could the RNGs near the workshops have behaved differently due to the presence of human bodies, or to increased variations in local electrical power, as compared to control periods when the environment was quieter? Such an explanation would require that RNG outputs be sensitive to factors such as electromagnetic or electrostatic fields, temperature, power fluctuations, degree of ionizing radiation, and/or physical vibration.

Such environmental influences are implausible explanations because (a) the two electronic RNGs were housed in grounded metal boxes to eliminate most electromagnetic influences, (b) the devices were designed to resist influences from electrostatic fields, temperature, power fluctuations, and physical vibration, (c) they drew power from the computers' regulated power supplies to avoid glitches due to power line fluctuations, and (d) the RM-60 radiation RNG responded only to ionizing radiation, the bulk of which was supplied by a sample of radioactive thorium, and in any case, the intensity of radiation was not linked directly to the generation of specific random bits.

In addition, all of the RNGs in the NPC were concealed in a central meeting room, so even if participants intended to physically influence the devices in some way, they did not know where the RNGs were located. Moreover, the electronic

RNGs employed logical exclusive-or (XOR) filtering on their raw binary outputs (against a counterbalanced sequence of 0s and 1s) to ensure that first-order biases were eliminated. Through the use of an XOR, even if an RNG catastrophically failed and started to produce sequences of, say, just 0s, the resulting mean of the generated bits would not drop to 0 but would quickly stabilize at 0.5. Glitches or momentary failures of any of the RNGs would have been easily detected because the sample variance would quickly decline to 0. Such radical departures from expectation were not observed in any of the data. Thus, through a combination of physical shielding, hidden locations, and logical design it seems unlikely that mundane environmental factors could account for the observed results.

Experimenter Effects

Another potential explanation is that these results were not due to a real-time field consciousness effect per se, but rather to the experimenters' intentions. This cannot be ruled out because the second author (F.H.A.) was responsible for the data collection, and he was fully informed about the nature of the experiment. However, F.H.A. was also involved in leading the workshops and data were collected automatically for 6 days without intervention, so it seems unlikely that F.H.A. spent much time consciously intending to influence the RNGs. Unconscious intentions cannot be ruled out.

Another source of possible experimenter effect was the data analyst (the first author, D.R.). This possibility arises because previous "retroactive-PK" experiments suggest that future observation of previously recorded random bits can result in significant deviations from chance expectation, indicating that real-time observation is not necessary in mind-matter interaction effects (Bierman, 1998). This retro-PK effect, analogous to Wheeler's delayed-choice experiment in quantum mechanics (Wheeler, 1978), was originally predicted based on a quantum observational theory of mind-matter interactions (Houtkooper, 2002). Its import here is that none of the recorded random bits used in this study were observed until D.R. analyzed them. This means the entire experiment could in principle be interpreted as a large-scale retro-PK experiment. To address this explanation in future studies one might ask analysts with different expectations to independently examine subsets of the data.

In conclusion, while post hoc, this study's outcome was consistent with previous reports (Radin, 2002) suggesting that fluctuations in mental coherence correlate positively with fluctuations in random physical systems. This approach to studying the nature of mind-matter interaction appears to be a fruitful one.

Notes

[1] Audio was played on a Yamaha Natural Sound HDD/CD Recorder, Model CDR-HD 1300.

[2] See http://noosphere.princeton.edu/rdnelson/reg.html for details, as of February 25, 2006.

[3] The Mindsong RNG is no longer manufactured; the Orion is available from http://www.randomnumbergenerator.nl/, as of February 25, 2006.
[4] See Aware Electronics (http://www.aw-el.com/), as of May 19, 2008.
[5] See http://www.stat.fsu.edu/pub/diehard/ for the software and description.
[6] See http://noosphere.princeton.edu/gcpdata.html#normalizing for a discussion of these RNGs.
[7] We thank Paul Bethke for writing the core data acquisition program and adding features to the software based on a design by the first author.
[8] AW-RADW.EXE, see http://www.aw-el.com/win.htm, as accessed on May 19, 2008.
[9] Named after the French inventor, Jean-Maurice-Emile Baudot, developer of the first high-speed telegraph in 1877, which was used throughout the world for over 70 years.
[10] This estimate, which is actually a t score with *df,* quickly approaches z as *df* increases.

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