

EFFECTS OF MASS CONSCIOUSNESS: CHANGES IN RANDOM DATA DURING GLOBAL EVENTS

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A long-term, continuing experiment is designed to assess the possibility that correlations may occur in synchronized random data streams generated during major world events. The project is motivated by numerous experiments that suggest that the behavior of random systems can be altered by directed mental intention, and related experiments showing subtle changes associated with group coherence. Since 1998, the Global Consciousness Project (GCP) has maintained a global network of random number generators (RNGs), recording parallel sequences of random data at 65 sites around the world. A rigorous experiment tests the hypothesis that data from the RNG network will deviate from expectation during times of “global events,” defined as transitory episodes of widespread mental and emotional reaction to major world events. An ongoing replication experiment measures correlations across the network during the designated events, and

the result from over 345 formal hypothesis tests departs substantially from expectation. A composite statistic for the replication series rejects the null hypothesis by more than six standard deviations. Secondary analyses reveal evidence of a second, independent correlation, as well as temporal and spatial structure in the data associated with the events. Controls exclude conventional physical explanations or experimental error as the source of the measured deviations. The experimental design constrains interpretation of the results: they suggest that some aspect of human consciousness is involved as a source of the effects.

Key words: consciousness research, mass consciousness, global consciousness, random number generator, RNG, GCP, mind-matter interaction, correlation

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INTRODUCTION

In recent decades mind and consciousness have again become a focus of scholarly research after half a century of psychology with a more behavioral approach.¹ Remarkably, it remains difficult to define for scientific usage what these terms mean. What is consciousness? Where is the mind? Is brain activity the answer to such inquiries? Is it possible that mind can directly affect the physical world?

These are difficult yet deeply interesting questions. The last, especially, demands not only scientific clarity, but an inclination for adventure in relatively uncharted intellectual waters. Since early in the 20th century, a few researchers working at the edges of physics and psychology have addressed questions like these in research on “extraordinary” capacities of human consciousness, including mind-matter interaction.² The Global Consciousness Project (GCP) was created to broaden these efforts. With contributions from scientists and engineers around the world, the Project has generated a unique body of random data collected in multiple parallel sequences, recorded continuously over more than a decade at widely distributed locations. The data can, in principle, be used to study any potential modulator of randomness, but the original purpose was to assess the possibility of a

subtle reach of consciousness in the physical world on a global scale.

A world-spanning network of physical random number generators (RNG) produces calibrated data meeting rigorous standards of randomness. The question we ask is whether these data may show transient deviations from randomness during instances of strongly focused, collective human attention and emotion. The devices produce a 200-bit trial every second at each of 65 locations around the globe, creating a record of random data that can be compared with the history of major events on the world stage. The hypothesis we test proposes that the data will display nonrandom behavior during times of “global events.” Specifically, we predict systematic deviations in the network data when there is a widespread sharing of mental and emotional responses. An on-going experimental test of the hypothesis, using a replication protocol, finds significant evidence of characteristic anomalies in the data corresponding to a wide range of events. The results indicate that something remarkable may be happening when people are drawn into a community of common attention or emotion. In this review we present the background, methods, and findings of the decade-long experiment, and address certain implications of the results.

Contemporary science typically considers consciousness to be an implicit function of brain physiology. Consciousness science has focused on how consciousness arises more than how it might impinge on or affect its environment. Nevertheless, for nearly a century, a small number of laboratory researchers have persisted in exploring questions at the margins of our understanding, developing over the years the experimental methods needed to study potential interactions between mind and matter.^{3,4} This area of research offers a unique window into the

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nature of consciousness by proposing direct manifestations of consciousness in the physical world. Evidence of such effects has been gathered under controlled conditions and the evidence raises puzzling questions. How is it possible to affect systems in distant locations with no physical or sensory connection? What could explain correlations between physical processes and the purely mental attention of human subjects? Can intentions alter processes in the physical world?

Laboratory experiments that address these questions often focus on the behavior of random systems. Although physical theory takes causality as a guiding principle, it also admits truly random phenomena (that is, phenomena that are, in principle, indeterminate, and not merely statistically uncertain). Quantum transitions are a familiar example of this weak causality, which is accepted in physics and is potentially of relevance to mind-matter research. Random phenomena are interesting for research on interactive consciousness because, in our current understanding, they are not completely explained by known deterministic causes—a characteristic they share with mind-matter interactions that challenge the completeness of conventional scientific models.

Among the early experiments that investigated the interplay of randomness and conscious activity were studies in which subjects were asked to influence macroscopic systems such as the position or face value of mechanically thrown dice.⁵ Since the 1960s, experiments have more typically used the high-speed generation of random numbers employing quantum electronic or radioactive sources. With the advent of the computer, automatic recording helped to ensure experimental control while also facilitating the accumulation of large databases. Improved experiments asked whether the random output of quantum sources could be biased by the mental intentions of subjects.⁶ In the latter part of the 20th century, replications of RNG experiments were carried out in laboratories around the world.^{7,8}

One prominent research program, the Princeton Engineering Anomalies Research (PEAR) laboratory,⁹ was founded by Robert Jahn in 1979 at Princeton University. In carefully controlled RNG experiments, the PEAR laboratory demonstrated a small, persistent effect. The difference from chance expectation is less than 1%, but compounded over the full database, it is highly significant, and it cannot be adequately explained by chance fluctuation or methodological error.¹⁰ The research extended the seminal early work of Schmidt⁶ and motivated replication experiments in several independent laboratories. Although many experimental questions about the RNG experiments remain (most notably the role of psychological variables), the research carefully documents anomalous departures from expectation associated with human consciousness, and specifically with directed intention.

Later versions of the RNG experiments used portable random sources, and by the early 1990s field work was feasible. In the field experiments, rather than instructing a participant to focus his or her intention on a laboratory RNG, the device was brought to locations where groups of people, blind to the experiment, were engaged in communal events and activities such as rituals, ceremonies, meetings, and musical concerts. The experiments asked whether continuously recorded sequences of random data might show structure during periods of group interac-

tion that involved shared emotions or deep interest.^{11,12} These experiments were subsequently replicated by other researchers.^{13,14} The results indicated that deviations in the random data were correlated with periods of group activity or “group consciousness,” especially when people involved reported a sense of coherence or resonance within the group. Tests in which data were collected in mundane or unfocused situations typically conformed to expected random behavior.

The field work raised a number of issues that became the basis of the GCP. Among these are questions about the effects of mere attention or mental engagement as opposed to directed intention: is the latter necessary, or might RNGs be generally responsive to the some aspect of consciousness?¹² Working in the field with groups also suggested using multiple devices in a distributed network: would multiple, simultaneous data streams reveal different effects?^{15,16} Would the RNGs correlate with each other and would this be a function of their proximity to the event or their mutual separation? Other questions concern the impact of various qualities that characterize events: their size, coherence, emotional tone, importance, human versus natural origin, and so forth.

In 1997, an effort was launched to engage these issues using a permanent, world-wide network of RNGs. The result was the GCP, which began data collection in August, 1998, and continues to this day.^{17,18} The GCP network is an instrument designed to capture indications of mind-matter correlations manifesting on a global scale. In practical terms, the project makes a conceptual leap from the single-device laboratory and field experiments that examined individual intention and group attention, respectively, to a multidevice experiment designed to look for effects of synchronized or coherent mass consciousness on a global scale.

METHOD

The proposition of global mind-matter correlations needs to be translated into an experimental hypothesis. Because we are breaking new ground, there is little history to guide hypothesis specification. We can, however, infer from the laboratory and field research described above that the effect would be small compared to the intrinsic noise scale of the data, and would most likely span a broad range of physical, social, and emotive conditions. We therefore work with a general hypothesis describing a range of conditions rather than a narrow set of parameters:

Periods of collective attention or emotion in widely distributed populations will correlate with deviations from expectation in a global network of physical RNGs.

The hypothesis avoids premature overspecification, but identifies the main elements we wish to test for: global correlations between collective conscious activity and the material world as represented by the physical RNG network. Experimentally, this general hypothesis is instantiated in a series of specific, rigorously defined hypothesis tests, each of which is compatible with the general statement. Technically, we propose a composite hypothesis that formulates our broadest guess of how global mind-matter correlations might be defined for the RNG network. We then proceed experimentally with a series of replications using simple hypotheses which are fully specified and can be compared quantitatively against the null hypothesis.

Because the term “global consciousness” may evoke ideas that differ from our intended usage, some clarification is warranted. Our approach to the GCP hypothesis is empirical. We employ an operational definition stating what we do in the experiment, thereby defining pragmatically the object of investigation. That is, for the formal experiment we treat global or mass consciousness as a set of operations, rather than as an intellectual or theoretical construct. We want to study X, and we do so by performing operations Y and Z. Specifically, we identify global consciousness as the outcome of the operations constituting the formal replication series. This produces a precisely defined experimental database that can be used to evaluate the general hypothesis.

The operational definition of global consciousness has a number of advantages. First, it avoids confusing our experimental proposal with a theoretical conjecture. The GCP hypothesis is not intended to describe a theoretical position, but is an experimental question motivated by prior research findings. Second, it allows us to determine a confidence level for deviations of well-defined statistics as a basis for further analysis. Finally, the replication series at the core of our definition is well suited to study an effect with low signal-to-noise ratio.

PROCEDURE

To set up a formal test, we first identify an engaging event. The criteria for event selection are that the event provides a focus of collective attention or emotion, and that it engages people across the world. Thus, we select events of global character but allow for variation in their type, duration, intensity, and emotional tone. In practice, events are chosen because they capture news headlines, involve or engage millions of people, or represent emotionally potent categories (eg, great tragedies and great celebrations).

Once an event is identified, the simple hypothesis test is constructed by fixing the start and end times for the event and specifying a statistical analysis to be performed on the corresponding data. The statistic used for most events is a measure of network variance. It is calculated as the squared Stouffer's Z across RNGs per second, summed across all seconds in the event. These details are entered into a formal registry before the data are extracted from the archive. We select and analyze an average of two or three events per month. The selection procedure allows exploration, whereas the replication design provides rigorous hypothesis specification for each event.

Because the project is unique, with no precedents to provide information on relevant parameters, we began with guesses and intuitions about what might characterize suitable, informative events. Field research on group consciousness¹¹⁻¹⁴ suggests that synchronization or coherence of thought and emotion may be important factors, so we typically select major tragedies and traditional celebratory events that bring large numbers of people together in a common focus.

Although many observers assume we can and should follow a fixed prescription to identify “global events” this is not straightforward. To give specific examples, we could select a disaster if it results in, say, more than 500 fatalities. But this would likely exclude slow-moving but powerfully engaging events such as

volcanic eruptions or major hurricanes, and it would fail to identify emotionally powerful, extremely important incidents like the politically disruptive attack that destroyed the Golden Dome Mosque in Iraq in February 2006, but killed relatively few people. What we try to do is to identify, with the help of correspondents around the world, events that can be expected to bring large numbers of people to a shared or coherent emotional state. The following is a partial, illustrative list of criteria that we use for event selection, with examples:

1. Suddenness or surprise. Terror attacks, especially when they galvanize attention globally.
2. Fear and compassion. Large natural disasters, typhoons, tsunamis, earthquakes.
3. Love and sharing. Celebrations and ceremonies like New Years, religious gatherings.
4. Powerful interest. Political and social events like elections, protests, demonstrations.
5. Deliberate focus. Organized meetings and meditations like Earth Day, World Peace Day.

Experience has led to considerable standardization, and for some kinds of events, predefined parameters can be applied. For example, events that repeat, such as New Years, Kumbh Mela, or Earth Day, are registered with the same specifications in each instance. For unexpected events, such as earthquakes, crashes, bombings, the protocol typically identifies a period beginning at or near the moment of occurrence, followed by time (typically six hours) for the spreading of news reports.

About half the events in the formal series are identifiable before the fact. Accidents, disasters, and other unpredictable events must, of course, be identified after they occur. To eliminate a frequent misconception, we do not look for “spikes” in the data and then try to find what caused them. Such a procedure, given the unconstrained degrees of freedom, is not statistically viable. There is no data mining, and there is no post hoc inclusion or exclusion of events. All events are entered into the formal experiment registry before the corresponding data are extracted from the archive. For details, see http://noosphere.princeton.edu/pred_formal.html. The analysis for an event then proceeds according to the registry specifications. All registered events are reported, whatever the outcome.

EQUIPMENT

The GCP is Internet based and employs a network of RNG devices installed at host sites (nodes) around the world. A central server receives data from the distant nodes via the Internet and incorporates them into a continually growing database archive. Each local node comprises a research quality RNG (Mindsong MicroREG by Mindsong, Inc., Orion RNG by ICATT Interactive Media) which is connected to a host computer running custom software. The software collects one data trial each second, a trial being the sum of 200 consecutive random bits of RNG output. The bit-sum is equivalent to tossing a fair coin 200 times and counting the heads, yielding random values with a theoretical average of 100 and standard deviation 7.071. The bits are generated from physical random processes in the RNG cir-

cuitry and are not created by a computer algorithm. Quantum tunneling produces a fundamentally unpredictable voltage in reverse biased diodes in the Orion and field effect transistors in the Mindsong. This is sampled at high speed to yield a random stream of 1, 0 bits. Each RNG is calibrated with at least one million 200-bit trials, processed using a custom suite of tests developed at the PEAR laboratory, which examines statistical distribution parameters (four moments), the arc-sine distribution, extreme value counts, run lengths, correlations, and autocorrelations. The devices are shielded, and an exclusive or (XOR) logic operation eliminates first order bias from physical causes.

The trials at each node are time stamped, written to the local disk, and then uploaded from the host computer to the network server in Princeton, NJ, at five-minute intervals. Custom data management software on the server stores all raw data in permanent archives. The result is an accumulating database of continuous parallel data sequences. The GCP design requires that the data be synchronized at one-second resolution. Host computers use network time protocol (NTP) or an equivalent for synchronization, and although we are aware of some failures, most hosts successfully maintain one-second accuracy. (Unsynchronized data do not affect the random output of RNGs, but might weaken or obscure the effects that depend explicitly on network synchronization.) Synchronous data generation means that we can treat the network as a single instrument, using statistical measures that address the whole network rather than treating the RNGs individually.

Figure 1 shows the location of host sites in the network, which grew to approximately 60 nodes in the first years of the Project, and since 2004, has been relatively stable with 60 to 70 operational nodes. We rely on volunteers to host and maintain the RNG device and software at each node. The geographical distribution of nodes is constrained by infrastructure limitations. Although we aim for a world-spanning network—ideally a deployment representative of world population densities—network coverage is poor in areas where Internet access is limited. For example, we do not have coverage in many parts of Africa and Asia.



Figure 1. Google map showing locations of all RNGs that have been in the network and contributed data. The distribution depends on Internet infrastructure. (Color version of figure is available online).

The GCP Website at <http://noosphere.princeton.edu> describes all aspects of the project, ranging over its history, context, and technology. One of the important features defining the Project is transparency, and the Website is a public access repository of information, including the entire archive of raw trial data, which is freely available for download. We maintain a complete record of the formal hypothesis tests and preliminary results from ongoing analyses, as well as contributions and critiques by independent, third-party investigators.

RESULTS

Through January 2011, over 345 rigorously vetted, prespecified events have been registered in the formal replication series, including tragedies and celebrations, disasters of natural or human origin, and planned or spontaneous gatherings involving great numbers of people. The events generally have durations ranging from a few hours to a full day. The Project registers about 30 formal events per year, and the data taken during these events comprise somewhat less than 2% of the 12-year, 25-billion trial database. The cumulative experimental result attains a level of 6.2σ (standard deviations) relative to the null hypothesis. The odds of a chance deviation of this magnitude are about a billion to one.

The formal result is obtained by first converting the test statistic for each event to a standard normal Z -score. The scores are averaged and the confidence level against the null hypothesis is given by the deviation of this average from zero. We find an average event Z -score of $\sim 0.33 \pm 0.054$, which yields the composite deviation cited above. The calculations assume that the RNGs have stable output distributions, and this has been extensively verified across the 12-year database.¹⁹ We do not, on the other hand, assume that the RNGs are perfect theoretical devices; the normalized Z -scores of the formal series are based on empirical estimates of mean and variance for each device, calculated from its entire data history. All analyses are checked for validity by running simulations on pseudorandom data sets, and the results are compared not only with theoretical expectation but with control distributions.

Figure 2 is a scatterplot of 346 Z -scores from the formal trials. The dashed horizontal line shows expectation and the solid line shows the mean deviation of all trials. This is obviously a small shift relative to the null distribution, but it is highly significant because of the statistical power of so many replications. Examination of the scatter gives a visual impression of the distribution, which tests as normal about the mean value; it also clearly displays homogeneity over time.

To display the consistency over events and the compounding significance of the small effect, we can plot the cumulative running sum of deviations from expectation as the replication series accumulates. The event data are shown together with results from a random simulation in Figure 3. The cumulative deviation of the actual event Z -scores is compared with the distribution of cumulative traces for 250 simulation series of Z -scores drawn randomly from the (0, 1) normal distribution. It is clear from Figure 3 that the event data are from a different population: they have a positive bias that is not present in the control distribution.

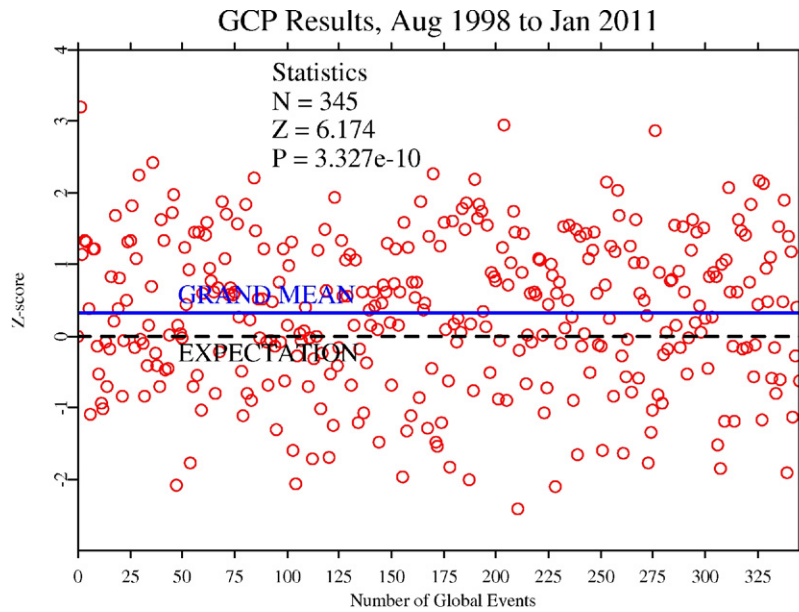


Figure 2. Scatterplot of 346 independent results. Dashed horizontal line shows expectation. Solid line shows mean deviation for all formal trials. (Color version of figure is available online).

A still more powerful control background is produced by resampling the nonevent data (98% of the database) to generate clones of the formal data series using the same parameters, but randomly offset start times for the events. Repeated resampling (also known as bootstrap sampling with replacement) produces the empirical distribution of expected scores, which is statistically indistinguishable from the random simulation. It provides a rigorous confirmation that the GCP database as a whole con-

forms to expected null behavior, whereas the behavior at the times of events displays a persistent deviation. Resampling also verifies that our analytical procedures do not introduce spurious correlations. This de facto control database necessarily contains any systematic nonideal behavior also present in the event data. Because the nonevent database exceeds the size of the event dataset by nearly two orders of magnitude, we can check for spurious effects with high precision.

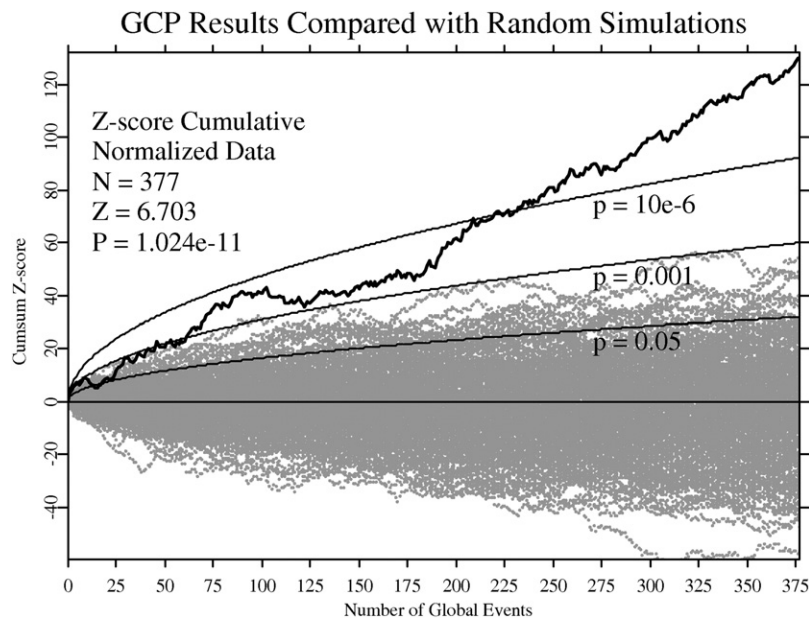


Figure 3. The bold jagged line shows the cumulative sum of deviations from expectation in the formal data. Gray lines show 250 simulated datasets drawn from the (0, 1) normal distribution. The horizontal line is null expectation and smooth parabolas show confidence levels.

The experimental trace in Figure 3 reveals several other important facts about the event data. First, although the trend is fairly steady, it fluctuates randomly about the average slope, as is expected for a weak effect dominated by random noise. Second, it is evident by inspection that the deviation is distributed smoothly over events; the cumulative rise is not dominated by a few outlier events. Formal testing shows the distribution of event Z-scores to be statistically indistinguishable from a normal distribution about the mean. Third, the average contribution of events is small.

This is an important point. The small effect size means that a single event cannot discriminate against the null hypothesis. Given an average effect size of .33, an estimated 80 events are needed, on average, to attain a significance of 3σ (P value .001) for a comfortable confirmation of the hypothesis. Even with a less demanding criterion, or a subset of events with a larger effect size, many replications are needed for an effect to be reliably identified. Simply put, the analysis of individual events cannot confirm the GCP hypothesis or identify anomalous effects during individual events. This is true even for extreme cases, such as the terror attacks on September 11, 2001.²⁰ The measured effect size is so small that statistical randomness entirely dominates when sample sizes are smaller than a few dozen events. Only in an accumulation of replications do anomalous effects rise above the level of statistical noise.²¹

RESEARCH PROGRAM

A major challenge for the GCP is how to study effects of the hypothesized global consciousness in data dominated by random noise. Our solution is a two-stage research program. First, the replication series, which we refer to as the formal experiment, yields an aggregate score that estimates the overall significance of the composite hypothesis against the null hypothesis. The formal experiment is ongoing, and it can be likened to a continuing meta-analysis, which updates the significance of a measured effect size with each new event.

The formal series, assessed by Z-scores representing the events, is the foundation for a broader research program to examine parametric details and potential models. We can also characterize the data based on the fundamental RNG trial scores: the second-by-second outputs during the events, for each RNG in the network. Whereas the event Z-scores concisely summarize the formal result, the trial scores index a complete description of the experiment: trial values with their time stamps for each device, the geographical position of the RNGs, and the event labels. A trial-level description permits analysis of any aspect of the experiment.

The secondary analysis program is motivated by the need to test various explanatory proposals against structure shown to be present in the empirical data. Some of the basic results are publicly available,^{18-20,22} but other important findings remain tentative and can be presented only in outline form.

Inter-RNG Correlation

Trial-level analyses demonstrate that the formal result is driven by the one-second network variance, whereas the RNG state probabilities and autocorrelation conform to expectation. The

network variance can be decomposed to show its relation to synchronized RNG-RNG correlations. Complete details are presented in a previous publication in which we show that analytical expressions of the formal result can be reduced to synchronized correlations between the RNG trials.¹⁸ Briefly, the chi-squared network variance, in terms of the RNG trial z-scores, $z_{r,t}$, is the sum of the trial variance, $\text{Var}[z]$, and a summation of trial pair-products. For N RNGs,

$$\chi^2 \approx (N-1)T_0 \overline{\langle z z_j \rangle} + T_0 \text{Var}[z] \approx NT_0 \langle r_{ij} \rangle + T_0 \text{Var}[z]$$

Here (ij) indexes all pairs of RNGs and T_0 is the length of the event in seconds. The overstrike denotes an average over all seconds, T_0 , and the brackets indicate an average over unique pairs of RNGs. The term $\langle r_{ij} \rangle$ represents the average of RNG-RNG correlations over all RNG pairs. The pair-product averages can be approximated by the average of Pearson correlations since the trial zs follow normal statistics and $T_0 \gg 1$. Furthermore, deviations in the one-second network variance are dominated by the correlation term, because the expected fluctuations of $\text{Var}[z]$ are relatively small, being of order $1/\sqrt{N}$.

Deviations in the network variance thus can be estimated by the average of products of pairs of trial values, $C1 = z_i z_j$, where z_i is the (normalized) trial value of the i th RNG for one second, and similarly for z_j . The elements of C1 include all possible combinations of RNG pairs with identical time stamps. It can be shown that the average value of C1 is proportional to the average linear (Pearson) correlation between RNGs.¹⁸ Under the null hypothesis, the expected average value of C1 is zero and, in this reformulation, a deviation in the mean value of C1 corresponds to the nonzero average of the event Z-scores.

The event-based scores and the trial-level formulation provide different but complementary perspectives. The event results confirm the formal predictions, and thus successfully identify an effect that we identify as operational global consciousness. The pair-product formulation provides more detailed information. Specifically, the C1 measure shows that the effect is associated with synchronized correlations of RNGs in the network, thus providing physical insight into how the effect arises during events.

It is perhaps useful to provide an intuitive picture of the synchronized correlations represented by C1. Imagine that the network of RNGs is replaced by buoys tethered at scattered locations across the ocean, and that the data acquisition consists of monitoring the height of each buoy, at each second, as it bobs up and down with the waves. The null hypothesis for C1 describes them bobbing randomly, without apparent correlation. A significant positive value of C1 corresponds to a substantial number of the buoys bobbing up and down in unison. This represents an anomaly because we do not expect wave motions at distant ocean locations to be correlated.

A Second, Orthogonal Correlation

In addition to C1, which expresses as a correlation the network variance test statistic that is formally specified in the GCP hypothesis registry and posted to the results tabulation, the secondary analysis looks for other independent effects and correlations. These are useful for understanding the data, and have a special

status because they represent structure that was not formally predicted by anyone involved in the experiment, including the main experimenter, prior to about 2005, some seven years into the project.

Of particular importance is a second, independent correlation that may be present in the network data. The C1 statistic suggests a class of correlation products, $z_i^n z_j^m$. A straightforward algebraic analysis shows that, for integer (m,n) , only the case $z_i^2 z_j^2$ is independent of C1. We refer to this correlation statistic as C2. It is a particularly interesting measure because it has exactly the same structural form as C1, but represents a unique, orthogonal correlation channel that is not addressed in the formal experiment. C1 can be regarded as a correlation of means, whereas C2 represents a correlation of variances.

As with C1, a positive deviation of C2 relative to expectation would indicate internode correlations. Analysis thus far is suggestive of a positive value, whereas control analyses using resampling on the entire database show that C2 conforms to null expectation in off-event data, and confirm empirically that C1 and C2 are uncorrelated.²² However, because the data base is complex, with events of several different types and durations, and variations in the makeup of the network over time, more work must be done to achieve confidence in the preliminary results.

Distance and Time

So far, we have shown that operationally defined global consciousness corresponds to correlations in the RNG network. Two important questions to consider are whether the correlations depend on the location of RNGs, and whether the correlation strength evolves in time as an event unfolds. The trial-level description provides a basis for spatial and temporal analyses because the correlation statistics contain the RNG locations and trial times as parameters.

An immediate challenge is to define appropriate measures for the tests. A test for spatial structure might examine where a particular event is located. However, even events with a definite location, such as earthquakes or catastrophic accidents, produce widespread reactions with geographical distributions that are difficult to characterize. But it is precisely the human response to events that our hypothesis predicts will correspond to the effects we record in the experiment. Consider the recent protests in the Middle East leading to the resignation of Egypt's President Mubarak. Although the turmoil was localized in Egypt, the response to the news of the event was global and complex. It is not clear without careful study what aspects of the reactions are relevant to the effect we posit, or how to determine the impact on different regions of the network.

Therefore, we cannot reliably define the locus of effects relative to the network or to the individual RNGs. In addition, as described earlier, the effect is driven by correlations between the RNGs rather than direct effects on the separate devices. Our primary measure relates to pairs of RNGs that are distributed over the globe with widely varying separations. Thus, the question of distance from the nominal source of the effect (which may be global in any case, eg, major religious holidays) is difficult to formulate in an obvious way.

In a similar sense, we note that, although the GCP hypothesis tacitly implies that effects will correspond to the event timing, it does not provide an estimate for effect timing or duration. Our "event" is not just, say, the moment of a devastating explosion; it includes both immediate and spreading reactions to the explosion. The GCP hypothesizes that an effect will correlate with the emotional engagement of large numbers of people, but because the experiment does not independently measure this engagement, we have only an approximate sense of when the effect begins or how long it might last. Should the event definition start at the moment of the celebration or beginning of the disaster, or before? Should our measurement period cover the immediate physical event or be extended to capture spreading news and widespread reaction? At the outset we do not have a metric which addresses these questions.

Despite these difficulties, both spatial and temporal structure are, in principle, detectable. Arguing from minimal assumptions based on the GCP hypothesis, we expect that a characteristic of structure in the data correlations will be smooth or consistent variation, both in time and across the network. Deviations dominated by smooth, large-scale changes in the data can be regarded as signatures of the posited global consciousness because they are not characteristic of excursions that occur purely by chance.

Spatial Structure

The geographical separation of RNG pairs provides a distance measure that is more tractable than assessments of the "distance from the event." The RNG pair separations are known to high precision and provide a useful perspective because any distance dependence of the effect will, in principle, lead to a corresponding dependence on pair separation. A general observation from the physics of spatially distributed complex systems is that correlations among constituents tend to weaken as their separation grows. Thus, a prediction based on physical intuition suggests that the correlation representing GCP effects will decrease as a function of RNG pair separation. We can test this with a linear regression of the correlation strength against the distance between RNGs. The prediction is that pairs of RNGs that are closer to each other will contribute more to the average correlation. In the image of bobbing buoys in the ocean, those separated by small distances will tend to bob together, but those separated by global distances less so, as if the swells stirred by the event have limited wavelength compared to the dimensions of the earth.

The geometrical separations of the RNG pairs can be calculated for each of the 10^{10} elements of C1 in the event data. We can then assess the regression of correlation against distance. A significant negative regression slope would provide evidence of spatial structure. Physical intuition predicts weaker correlations as separations increase, and the broad deployment of the GCP network allows us to perform the test over distances that range from a few meters out to the earth's diameter.

Again, there is suggestive evidence for such regression, with more work needed to understand the form of the dependence and whether it applies uniformly or only for certain kinds of events. These are challenging questions for analysis because of the small effect size. However, simulations using a numerical model demonstrate that a linear dependence on distance does provide a good representation of the data.

Temporal Structure

The GCP hypothesis proposes that data correlations will correspond to the human response to events, which first grows as an event becomes the focus of global attention, then persists for a time while people attend to the focus, and finally dissipates as attention wanes. The GCP test cases (events) are likely to include sections of null data before or after the effects because the formally specified periods make generous estimates of the event durations in order to maximize the likelihood that the full response is included in an event. The expected temporal pattern in event data will thus be periods of inter-RNG correlation during the effect, typically bracketed by random data.

If this hypothetical picture is correct, physical intuition suggests ways to characterize the time structure. For example, the power spectral density of correlations taken as a time series would show an anomalous weight at low frequencies, relative to the expected density for chance deviations of correlation. Additionally, given two independent measures, C1 and C2, that show effects during the events and that are both driven by the same source, we expect correlations between the two measures during the actual effect, but not otherwise. This and other approaches to defining the temporal structure are the subject of ongoing research.

MODELS AND THEORY

The development of multiple measures of structure in the GCP data is an important step toward modeling. If we have robust results representing temporal and spatial structure in the event data, they can complement the formal measure of internode correlation as input for theoretical models of the deviations.

Three classes of models to consider are: (1) conventional explanations in terms of physical and electromagnetic fields, or conventional methodological errors or biases; (2) unconventional information transfer via fortuitous selection of events, experimenter intuition, or retroactive influence from future results; and (3) field-like models of consciousness or information sourced in individual human minds, or a nonlinear field representing a dynamical interaction among minds.

Explanations of the formal experiment based on spurious effects can be rejected for the reasons detailed in descriptions of the GCP research program, and on the basis of empirical studies.^{18,20} Methodological leaks and systematic biases are precluded, respectively, by event specification and registration procedures that effectively blind the analysis, and by resampling controls that find no evidence of biases in the off-event data. Such explanations are also inconsistent with the multiple indications of unexpected data structure outlined in the previous section.

Proposals based on electromagnetic (EM) perturbations (extra load on the grid, excess mobile phone usage, and so forth) are among the most frequently advanced conventional explanations of the GCP results, but they can be challenged on a number of points. Design features of the RNGs and the network protect the data generation from biases, as previously described. Even if these protections should fail, it is unlikely that local EM fields could give rise to distant correlations among the RNGs. Finally, direct analysis shows no evidence of diurnal variation in the

RNG outputs, whereas ambient EM fields arising from the daily cycle of human activity would presumably induce a corresponding variation in the data. We do not see current proposals based on ordinary EM fields as viable explanations for the measured global correlations and data structure, but it would be premature to exclude entirely the possibility of subtle EM effects.

Models involving intuitive selection and retroactive information are variants of a theoretical position from parapsychology advanced to explain psi functioning.²³⁻²⁵ The general idea is that expectations and attitudes about the experiment play a role in determining the outcome. In the data selection case, the key notion is that deviations result from a fortuitous designation of the times of selected events rather than an actual change in the data. The measured anomalies are attributed to the selection of unlikely data excursions in a naturally varying sequence. The fortuitous selection is assumed to derive from the experimenter's intuition or precognition of the eventual result, which informs the choice of events, their timing and the test procedures.²⁶ The GCP results (C1) have been analytically tested against an explicit version of this model.²² The tests nominally reject the proposal, but are not sufficiently powerful to draw definitive conclusions. Strengthening or rejecting the preliminary conclusions awaits refinement of the secondary analyses. In principle, a selection model might be capable of explaining the formal result, but would have serious difficulty with a second correlation or other structure in the data.

The retroactive information proposal is based on time symmetry arguments.²⁵ It suggests that experimental outcomes are linked to the future in a manner that is analogous to the apparently causal past. It implicates consciousness directly by claiming that unexpected data correlations can be explained as a desired future actualizing in the present. Retrocausal models are not developed to the point where they can be tested quantitatively against the GCP data, but we note that no simple version could easily explain multiple indicators of structure in the event data.

Finally we consider field-type models associated with human consciousness. A simple version is analogous to ordinary physical models in that it posits a field generated by a distribution of sources. The connection to consciousness is made by associating the field sources with conscious humans, whereas the field dynamics that explain the RNG correlations derive from the coherence of human activity during events. This proposal can accommodate all the internode correlations and structure seen in the data. However, it remains phenomenological because it does not explain how the field arises in terms of underlying principles.

A more complex proposal is that individual minds may be mutually interactive. In this view, interactions among the minds of individuals are responsible for an emergent field or property that depends on individual consciousness but is not wholly reducible to it. The proposal suggests that the dynamic and interactive qualities of consciousness also involve subtle interactions with the physical world and that these interactions are responsible for certain anomalous phenomena, such as are found in the GCP event experiment. It can be construed as embodying in a formal way the ideas of such thinkers as Teilhard de Chardin,

describing a “noosphere” of intelligence for the earth,²⁷ or Arthur Eddington, conceiving a “great mind.”²⁸

DISCUSSION

The development of a new experiment presents challenges that can only be dealt with by trial and error illuminated by analytical results. Many aspects of the GCP experiment have no direct precedents. For example, selection and parameter decisions for the early tests were necessarily guesses. Although the hypothesis testing was fully scientific, no objective criteria were available for specifying the target events (other than untested, arbitrary schemes). This has been a concern of critics accustomed to formulaic parameter specification, and it deserves discussion.

As described earlier in this paper, our research program has several levels:

1. A general hypothesis states that we expect to find correlations linking world events and data anomalies. We test it by sampling a variety of events, expecting a range of effects depending on factors such as event importance, emotional impact, valence, and surprise. Events are chosen that are expected to engage large numbers of people and generate shared emotions. But we have at the outset only intuition and opinion to guide their selection.
2. Despite this difficulty, specific hypothesis tests rigorously evaluate instances of the general hypothesis. The test parameters are defined prior to accessing the archived data. The test statistics are standardized, fully characterized, and independent. The results gradually (due to the small average effect size) educate us as to the types of events that do yield correlations, and they teach us, slowly, about appropriate specifications.
3. The composite across the accumulating specific tests is akin to a meta-analysis of formal replications, which yields a confidence level for the existence of anomalous deviations corresponding to events. This constitutes our operationally defined consciousness correlations.
4. Secondary analyses are designed to characterize the correlations and establish parameters and constraints for the data anomalies. These become the necessary and appropriate input for modeling effects and identifying promising theoretical directions.

The first two items above are the core of a research program designed to permit exploration of unknowns while accumulating sound experimental data. A very small effect size means we need dozens of replications to achieve reliable statistics, so learning enough to set firm rules for event selection requires many years, given that we identify about two or three events per month and that we study several kinds of events. A decade of experience suffices to establish general guidelines for the types of events we can expect to show effects, and provides guidelines for time periods that are adequate to capture the anomalous effects. The accumulating results of secondary analyses feed back to such standards.

No current model is sufficiently developed to explain the experiment. Typically, theory and experiment work together to guide

and advance research. However, the interplay between theory and experiment is weak when experimental hypotheses are merely empirical, without a well-developed theoretical basis. This is the case for the GCP event experiment, despite its robust result. It establishes a phenomenon but does not test any proposed mechanism or theory. From this perspective, the result is an extreme example of a scientific anomaly in that it calls for both physical and psychological explanations, without providing a clear theoretical link to either one.²⁹ Of course, anomalies are not off-limits to scientific study, but they require a period of empirical effort before theoretical tools can be brought to bear on the problem.

The empirical results lay the groundwork for a progressive investigation of the hypothesis of operationally defined global consciousness, which we can summarize in a few basic questions. We have partial answers to these questions, and future research will test and elaborate our provisional conclusions.

1. Is the effect physical? We have argued from the data that models based on selection bias, whether from intuition or methodological flaws, are unlikely. In contrast, indications of structure in the data are consistent with field-type models that imply true (physical) data anomalies.²² All the tests of temporal and spatial structure as well as the derivation of the orthogonal correlation statistic derive from physical and analytical considerations.
2. Is the effect anomalous? Conventional physical models are not viable. Beyond the empirical testing that indicates EM fields have no effects on the network, it is difficult to imagine that conventional fields could generate the global data correlations we measure, which are synchronized over thousands of kilometers.¹⁸ This synchronization of correlations is both a strong argument against conventional proposals and a useful constraint for any detailed model of an anomalous effect.
3. What characterizes a global event? The experiment depends on defining “collective attention or emotion” to identify suitable events for study. This is the starting point for determining what underlies the effect, and it is fundamentally an empirical question. Events can be classified into various psychological and sociological categories, and the categories’ relative importance for operational global consciousness can be tested. An important question is whether different types of events have discernibly different structural signatures in the data.

CONCLUSIONS

The GCP is a long-term experiment that asks fundamental questions about human consciousness. Our review describes evidence for effects of collective attention—operationally defined global consciousness—on a world-spanning network of physical devices. Careful analysis examines multiple indicators of anomalous data structure correlated specifically with moments of importance to humans. The findings suggest that some aspect of consciousness may be a source of anomalous effects in the material world. This is a provocative notion, but it is arguably the best of several alternative explanatory directions. The convergence of several independent analytical findings provides strong evidence for the anomalies, and to the extent these can be integrated into scientific models they will enrich our understanding of consciousness.

Although a full exploitation of the structurally rich database is in early stages, substantial progress has been made in under-

standing the GCP experiment. Physical insight into the nature of the effect has already been gained by the analysis, and this allows us to begin discriminating between theoretical approaches while providing tools for refinement of the general hypothesis. Future efforts will emphasize the human and participatory aspects of the events we study.

We have argued that the GCP experiment is not easily explained by conventional or spurious sources. Instead, we provisionally conclude that the anomalous structure is correlated with qualities or states of collective consciousness activity. Although social and psychological variables are challenging to characterize, an obvious suggestion is to look for changes in the level of “coherence” among the people engaged by the events. Defining this construct and developing it empirically will be important for further progress.

In sum, the evidence suggests an interdependence of consciousness and the environment, but the mechanisms for this remain obscure. Substantial work remains before we can usefully describe how consciousness relates to the experimental RNG results beyond the empirical correlations. Our findings do not fit readily into current scientific descriptions of the world, but facts at the edges of our understanding can be expected to direct us toward fundamental questions. As Richard Feynman remarked, “The thing that doesn’t fit is the thing that is most interesting.”³⁰

It is important to consider different theoretical scenarios. Quantum entanglement, retrocausation, active information fields, and other ideas have been discussed in this context, but these notions drawn from physics have only tenuous connections to the GCP experiment. It is currently hard to see any obviously good fit, but the research and especially the extended analysis provides much needed input by establishing parameters that can help discriminate models.

More broadly, the GCP results are of relevance for the study of mind and brain because they bear directly on fundamental questions of consciousness. Research in conventional brain science tends to focus on the neural correlates that give rise to consciousness, and tacitly or explicitly assume that consciousness reduces to brain activity. The GCP results urge us to ask a harder question: Are there direct correlates of consciousness to be found outside the brain? The question is challenging because it posits or points to phenomena that are anomalous and hence mysterious from a conventional standpoint. The search for understanding of mind and brain obviously must change dramatically if consciousness correlates are found in the broader world.

Finally, the GCP results inspire deeper questions about our relation to the world and each other. Might we find that the best model, after all, resembles a coherent, extended consciousness akin to Teilhard de Chardin’s aesthetic vision of a noosphere? Although this is a possibility that is currently beyond the supply lines of our scientific position, the experimental results are consistent with the idea that subtle linkages exist between widely separated people.

What should we take away from this scientific evidence of interconnection? If we are persuaded that the subtle structuring of random data does indicate an effect of human attention and emotion in the physical world, it broadens our view of what consciousness means. One implication is that our attention matters in a way we may not have imagined possible, and that

cooperative intent can have subtle but real consequences. This is cause for reflection about our responsibilities in an increasingly connected world. Our future holds challenges of planetary scope that will demand both scientific clarity and mutual cooperation. On this we should be of one mind.

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