Exploring Global Consciousness

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Abstract

The Global Consciousness Project (GCP) is a long-term experiment which investigates the proposition that direct correlations of mind and matter may occur on a global scale. The Project is motivated by numerous experiments which suggest that the behavior of random systems can be altered by directed mental intention. Since 1998, the GCP has maintained a global network of random number generators (RNGs), recording parallel sequences of random data at over 60 sites around the world. In a novel experimental approach to the question of mind-matter interaction, the GCP proposes 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 on-going replication experiment tests this hypothesis by measuring correlations across the network during the designated events. The result of over 300 formal hypothesis tests is highly significant. A composite statistic for the replication rejects the null hypothesis by more than 5 standard deviations. Further analysis reveals evidence of 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 results suggest that some aspect of human consciousness may be involved as a source of the effects. The paper presents a comprehensive review of experimental methods and results after more than 11 years of continuous operation.

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Introduction

> *The universe is of the nature of a thought or sensation in a universal Mind... To put the conclusion crudely — the stuff of the world is mind-stuff. As is often the way with crude statements, I shall have to explain that by "mind" I do not exactly mean mind and by "stuff" I do not at all mean stuff.*
>
> -- Arthur Eddington[1]

Where is the mind? Is it wholly in the brain? If not, what are its extended qualities? Are there direct effects of mind in the physical world? Is there such a thing as collective mind? Could there be a global consciousness?

These are difficult yet deeply interesting questions. They demand not only scientific clarity, but an inclination for adventure in uncharted intellectual waters. Since early in the 20th century, researchers working at the edges of physics and psychology have addressed questions like these by looking at the extraordinary capacities of human consciousness. The Global Consciousness Project (GCP) was created to broaden these efforts. With contributions from scientists, engineers, artists, and business people from around the world, its purpose is to study the possibility of a subtle reach of consciousness in the physical world on a global scale.

The GCP maintains a world-spanning network of instruments designed to produce continuous random data and asks if these data may be altered during special instances of collective human activity. The instruments produce data 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 streams of data from these random sources will display non-random behavior during times of "global events." Specifically, we predict systematic deviations in the data streams when there is a widespread sharing of mental and emotional responses. An on-going experimental test of the hypothesis, using operational definitions in a replication protocol, finds significant evidence of characteristic anomalies in the data for 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 paper we present the background, methods, and findings of the decade-long experiment, and address certain implications of the results.

The Edge of Consciousness Science

Over much of the modern scientific era, questions concerning the nature of human consciousness have largely been ignored by mainstream science. 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.[2] This area of research offers a unique window into the nature of consciousness by proposing direct manifestations of consciousness in the physical world. Evidence of these "impossible" phenomena gathered under controlled conditions raises puzzling questions. How could it be possible to obtain information from distant locations with no physical or sensory connection? What could explain correlations between physical processes and the purely mental attention of human subjects? Can there be direct effects of intention in the physical world? Is there a sense in which mind is present in the world beyond the brain?

Laboratory experiments which address these questions often exploit a loophole in the causal framework of physical theory by focusing on the behavior of random systems. Although physical theory takes causality as a guiding principle, it also admits truly random phenomena (that is, phenomena which are in principle indeterminate, and not merely statistically uncertain). A truly random physical process may be influenced by causes, but it is not wholly determined by them. Quantum transitions are a familiar example of this weaker causality which is accepted in physics, and is potentially of relevance to mind-matter research. Random phenomena are interesting for experimentation precisely because, in our current understanding, they are not fully explained by deterministic causes, and because research on mind-matter interactions also challenges the completeness of conventional views of causality.

Among the early experiments which investigated the interplay of randomness and conscious activity were studies in which subjects were asked to influence macroscopic systems.[3] Since the 1960's, experiments have largely 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. Improved experiments asked whether the random output of quantum sources could be biased by the mental intentions of subjects.[4] In the latter part of the 20th century, replications of random number generator (RNG) experiments were carried out in laboratories around the world.[5,6]

One prominent research program, the Princeton Engineering Anomalies Research (PEAR) laboratory,[7] was founded by Robert Jahn in 1979 at Princeton University. In carefully controlled RNG experiments, the PEAR lab demonstrated a small, persistent effect equivalent to a few parts in 10,000. Compounded over the full database, the effect is highly significant and cannot be adequately explained by chance fluctuation or methodological error.[8] The research extended the seminal early work of Schmidt[4] and motivated replication experiments in several independent laboratories. While 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 a rituals, ceremonies, meetings and musical concerts. The experiments asked whether continuously recorded sequences of random data might show structure during periods of group interaction which involved shared emotions or deep interest.[9,10] These experiments were subsequently replicated by other researchers.[11,12] The results indicated that deviations in the random data correlated with periods of group activity, especially when the people involved reported a sense of coherence or resonance with the group. Tests in which data were collected in mundane or unfocused situations conformed to expected random behavior.

The field work raised a number of issues which became the basis of the Global Consciousness Project. Among these are questions about the consequences of running multiple devices in a distributed network: would multiple, simultaneous data streams reveal different effects?[13,14] 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 concerned the impact of various qualities that characterize events: their size, emotional tone, importance, human vs. natural origin, etc.

In 1997 an effort was launched to study these questions using a permanent, world-wide network of RNGs. The result was the Global Consciousness Project, which began data collection in August, 1998 and continues to this day.[15,16] The GCP network is an instrument designed to capture indications of mind-matter correlations manifesting on a global scale. A fanciful conception of the network is that of an electroencephalogram or EEG for the world. In practical terms, the project makes a conceptual leap from the single-device laboratory and field experiments which examined intention and group consciousness, respectively, to a multi-device experiment designed to look for related effects on a global scale.

An Experimental Hypothesis

To proceed, the proposition of global mind-matter correlations needs to be translated into an experimental hypothesis. Since we are breaking new ground, there is little history to guide hypothesis specification. Nevertheless, we can infer from the laboratory and field research described above that the effect would most likely span a broad range of physical, social, and emotive conditions and would be small compared to the intrinsic noise scale of the data. We therefore make 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 random number generators.***

The hypothesis avoids premature over-specification, but includes 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. To use technical language, we propose a *composite hypothesis* which 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.

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. We thus explore events of global character, but allow for variability in their type, duration, intensity and emotional tone. Once an event is identified, a test hypothesis is constructed by fixing the start and end times for the event and specifying a statistical analysis to be performed on the corresponding data. These details are entered into a formal registry before the data are extracted from the archive. The analysis for an event then proceeds according to the registry specifications, yielding a test statistic relative to the null hypothesis. These individual results become the series of replications that address the general hypothesis and ultimately are combined to estimate its likelihood. To eliminate a frequent misconception, we note that 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 obviously inappropriate.

A central experimental problem for the GCP is how best to study a conjectured global consciousness effect in data dominated by random noise. The experiment must treat an effect which is not only small in size, but also incompletely specified. The solution we adopt is to implement a two-stage experimental program. First, the replication series, which we refer to as the formal experiment, yields an aggregate score which estimates the overall significance of the composite hypothesis against the null hypothesis. The formal experiment is ongoing and the aggregate result can be likened to a continuing meta-analysis which updates the significance of a measured effect size with each new event. Second, the formal experiment identifies a data set for further analysis since it provides a level of confidence that the hypothesized effect is indeed represented in the event data. This approach allows us to explore a range of factors in secondary analyses without imposing constraints prematurely.

How it Works

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 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. The bits are generated from physical random processes (specifically, quantum tunneling) in the RNG circuitry and are not created by a computer algorithm. The GCP data are thus at once truly random and derived from natural physical processes.

The trials are time-stamped, written to the local disk and then uploaded from the local hosts to the network server in Princeton, NJ at 5-minute intervals. Custom software on the server stores the data in permanent archives with all data synchronized at one-second resolution. The result is an accumulating database of continuous parallel data sequences. The 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 nodes in the current network, which has grown to approximately 65 nodes since the start of the Project. We rely on volunteers to host and maintain the RNG device and software at each node. The geographical distribution of nodes is opportunistic in the sense that we are constrained by infrastructure limitations of the Internet. While 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.

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.

Figure 1. Location of nodes (RNGs) in the world-spanning GCP network as of late 2009. Internet infrastructure constrains the distribution. An interactive map and table available on the GCP website provides details for each node.

The Formal Replication Experiment

Through January 2010, over 300 rigorously vetted, pre-specified 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 less than 2% of the 11-year, 22-billion trial database. The cumulative experimental result attains a level of 5.3σ (standard deviations) relative to the null hypothesis. The odds of a chance deviation of this magnitude are about 10 million to 1.

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 0.311 ± 0.059, which yields the 5.3σ composite deviation cited above. The calculations assume that the RNGs have stable output distributions, and this has been extensively verified across the 11-year database. All analyses are checked for errors by running simulations on pseudo-random data sets. The primary result has also been confirmed by bootstrap estimates using random re-sampling from the entire database. A demonstration of the bootstrap analysis is shown in Figure 2.

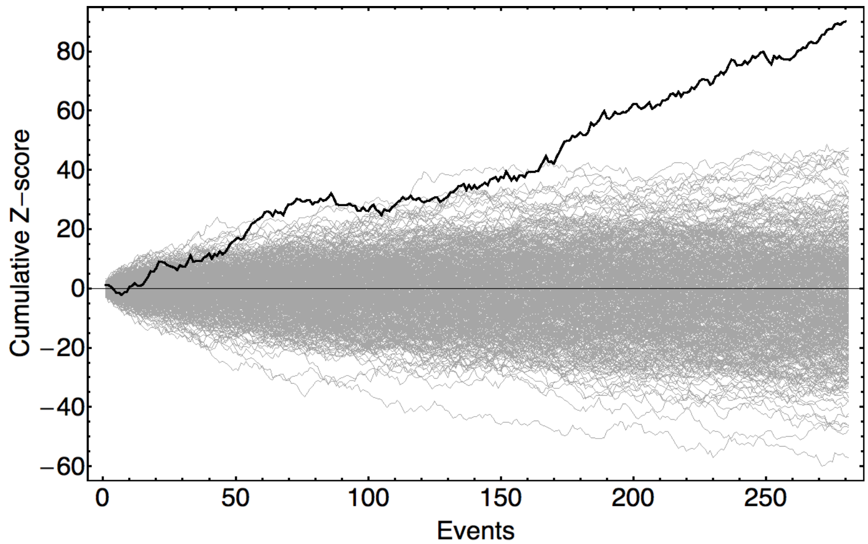

Figure 2. Bold curve shows cumulative total deviation of results for all formal hypothesis tests. The cloud of gray curves shows the results of 500 re-sampling “control” tests with the same specifications but randomly offset start times. Expectation is the horizontal line at zero.

The figure compares the cumulative deviation of the actual event Z-scores with the cumulative traces of Z-scores for identical event periods sampled at random start times. The bold line shows the event data and the gray traces show 500 re-sampled data series. The graph plots the chronological deviations from expectation. The endpoint of the bold trace corresponds to the composite result for the replication. It is clear from Figure 2 that the event data have a positive bias which is not present in the database as a whole. A full bootstrap analysis finds an empirical deviation of 5.5σ for the real data against the re-sampling distribution, in close agreement with the theoretical result. The re-sampling analysis provides a rigorous confirmation that the GCP database as a whole conforms to expected null behavior, whereas the behavior at the times of events displays a persistent deviation. It also verifies that our analytical procedures do not introduce spurious correlations.[16]

The experimental trace in Figure 2 reveals several other important conclusions 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. Third, the average contribution of events is small. This is a crucial point, as it tells us that a single event cannot discriminate against the null hypothesis; many events are required in order to reliably detect and measure the effect. From the measured effect size of 0.311, an estimated 90 events are needed to attain a significance of 3σ (p-value 0.001), which is at the lower bound for a comfortable confirmation of the hypothesis. Even with a less demanding criterion, it is obvious that many replications are needed for an effect to be discriminated.

Statistical Noise and Effect Size

Although the effect is, on average, too small to allow for the analysis of individual events, we can still ask if there are events which might yield to individual analysis and provide us with further insight. For instance, if the registered event times exclude some nearby periods of substantial deviation, then including the unexamined data might augment the confidence level of an individual event. One case that stands out in this respect is the terrorist attack of September 11, 2001.

The original analysis for the September 11 event yields an event Z-score of 1.87 ($p = 0.031$).[17] However, the formally specified duration of four hours and 10 minutes hardly reflects the full impact of the 9/11 attacks and the worldwide reactions to them. In a series of *post hoc* analyses, data extending beyond the formal event time were examined to see if the network deviations persisted while the world-wide reaction of shock, grief, compassion and anger unfolded. The analyses show that the deviations did indeed persist for an extended period of over two days at roughly the same level as measured in the formal event. However, when corrected for multiple analysis and informed choice, the probability of the deviation measured in the *post hoc* test is roughly the same as the registered event period. Thus, the extended 2-day deviation around the September 11 event does not confirm the GCP hypothesis at a higher level of statistical confidence. This conclusion is supported indirectly by comparing the 9/11 event with the rush-hour bombings in Madrid, 2004 and London, 2007, which were similar in character. Neither the Madrid or London events showed significant deviations in similar analyses.

We conclude from these *post hoc* assessments that the significance of single event data, even when data-mined outside the times of the formal specification, remains ambiguous or marginal. This is an unavoidable consequence of the small effect size and reinforces our conclusion from the replication experiment that many events are needed to confirm the general hypothesis, even for events which involve the largest numbers of people or have the greatest emotive impact. Only in combinations of many separate tests do the effects achieve clear statistical significance.

This situation is, of course, common across scientific disciplines. Psychological and clinical studies often are designed to assimilate thousands of trials over years of study. An example from the physical sciences describes similar conditions for data collection at the international Large Hadron Collider (LHC) experiment. The consortium released the following statement in 2008: “... the LHC is due to begin testing and collecting data this September. It will be six to seven years, however, before any results can be analyzed. The reason for this is that the particle events under investigation will only occur in a minority of the interactions and, even then, their presence will be masked by 'noise' generated from other interactions. The events are also very short-lived, lasting only for fractions of a second. As a result, data of sufficient statistical power will take the best part of a decade to collect.”[18]

Defining Global Consciousness

It is essential to clarify what we mean by “global consciousness” because the term evokes many ideas that differ from our intended usage. Because our approach to the GCP hypothesis is strictly empirical, we adopt an operational definition, stating clearly what we do in the experiment, thereby defining pragmatically the object of investigation. That is, we treat global consciousness as a set of operations, rather than as an intellectual construct. We want to study X and we do so by performing operations Y and Z. This yields a precise definition of global consciousness for the purposes of this experiment. Thus, when we say "operational global consciousness" (OGC) we refer to the operations constituting the formal replication series that is used to evaluate the general hypothesis. In other words, we implement hypothesis tests by giving prescriptions for measuring correlations between data deviations and world events. The degree to which the hypothesis is valid is measured by performing the replication experiment. Although we denote the correlation as global consciousness, we do not propose an underlying mechanism for it, nor do we attribute it to a conscious agency.

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 specify a confidence level for experimentally established deviations prior to further analysis. Finally, the replication series at the core of our operational definition is well-suited to an effect with low signal-to-noise ratio. As we have shown, single events are not amenable to analysis because the small effect size limits statistical power. From the point of view of our operational definition, single events are not taken as instances of OGC since they do not confirm the general hypothesis at a high confidence level.

A Research Program

> *The scientific mind does not so much provide the right answers as ask the right questions.*
>
> -- Claude Levi-Strauss[19]

The formal experiment can be summarized as follows. The general hypothesis is addressed experimentally by replicating explicit tests of events. The outcome of each test is expressed as a Z-score which represents its deviation from the null hypothesis. Confirmation of the general hypothesis is tested by comparing the average value of the event Z-scores to zero, the null expectation. The average Z over nearly 300 registered events is $0.311 \pm .059$, a deviation of more than 5 standard deviations, equivalent to roughly one chance in 10 million. Extensive analyses confirm that this value is not skewed by outliers and is a reliable estimate of the effect size. We conclude that the event experiment successfully measures global consciousness in the operational sense discussed earlier, and that the general hypothesis is confirmed to a high level of confidence.

The formal experiment is part of a broader experimental strategy in which models are proposed and tested to gain insight about the nature of the effect. The first step is to characterize the structural details of the event data. To achieve this, the formal event Z-scores need to be expressed directly in terms of the more fundamental RNG trials. Whereas the event Z-scores concisely summarize the formal result, the RNG trials index a complete description of the

* Our approach differs from research which employs a fixed significance criterion to test hypotheses such as the P-value < 0.05 often used in the social sciences. Since there is no explanatory theory or precedent for setting expectations, we simply calculate a level of confidence that the replication shows non-chance variation. In terms of our operational approach, the confidence level of OGC for the event data is 99.99999% against the null hypothesis.

experiment: trial values with their time-stamps, the geographical position of the RNGs, and the event labels. A trial-level description thus permits analysis of any aspect of the experiment. In addition, models which advance explanations can be tested against any trial-level structure shown to be present in the data. The goal of the data characterization is thus to determine an accurate statistical description of the event data in a form appropriate for model testing. We show in the following section how this is achieved with a single trial-level statistic.

Models may attempt to expand on the general hypothesis or propose alternate explanations for the formal result. For example, an obvious approach suggested by the general hypothesis is a field-type model in which RNG behavior is predicted by the value of a field present at the RNG locale. The field might depend on the character and distribution of mental and emotional activity in the world population, or other appropriate variables. A proposal of this type predicts that temporal and spatial field variations will result in corresponding structure in the data. Empirical evidence of such data structure would thus be supportive of these models. We will return to the topic of modeling later in the paper.

Conventional explanations can also be proposed for the anomalous findings. One might suppose that the result is due to experimental flaws such as the inadequate shielding of RNGs from background electromagnetic fields or bias due to methodological errors. The GCP design addresses these eventualities by physically shielding the RNGs from EM fields and by logical operations in software which cancel output bias arising from environmental influences. The replication protocol ensures that data remain archived until an event is fully specified so that methodological “leaks” leading to biased data selection are precluded. In general, a spurious result will only obtain if the network produces systemic deviations of precisely the kind we measure, or if the deviations are introduced by a flawed analysis procedure.

An important design feature of the GCP is that data are generated continuously, so data that do not correspond to events are available for baseline comparisons. This *de facto* control database will necessarily contain any systematic non-ideal behavior also present in the event data. Since it exceeds the size of the event database by nearly two orders of magnitude, the off-event control data allow us to check for spurious effects with high precision. The re-sampling analysis shown earlier in Figure 2 is an example of a control which uses off-event data.

Data Characterization

In this section we briefly describe the trial-level statistic which will be the basis for analyses and model testing.[†] Details are presented in a previous publication.[16] There we show that analytical expressions of the formal result can be reduced to synchronized correlations between the RNG trials. The correlation elements are expressed as the 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. The elements of C1 include all possible combinations of RNG pairs, subject to the restriction that the pair-products have identical time-stamps. It can be shown that the average value of C1 is proportional to the average linear (Pearson) correlation between RNGs.

Under the null hypothesis, the expected average value of C1 is zero and, in this reformulation, a

† For these secondary analyses, the full database of 300+ formal events is reduced to 280 by excluding events longer than 24 hours and some that are incompatible with the C1 analysis.

deviation in the mean value of C1 corresponds to the non-zero average of the event Z-scores. The pair-product formulation yields a slightly reduced significance (4.9σ versus 5.3σ for the formal event tests) due to different weighting procedures in the two formulations, but this difference is not statistically meaningful.

The event and trial-level formulations lend themselves to different interpretations. The event formulation tells us that the formal predictions are successful in identifying OGC. The pair-product formulation provides more information. It yields evidence that OGC is associated with a precise trial-level statistic, namely the synchronized correlations of RNGs in the network. Both formulations confirm the general hypothesis at a high confidence level, but the formulation in terms of C1 provides physical insight into how OGC arises during events.

While the bi-linear form of C1 may be familiar for some readers, it is perhaps useful to provide an intuitive picture of the synchronized correlations it represents. 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 buoys which bob randomly, without apparent correlation in their instantaneous heights. A significant positive value of C1 describes a situation in which the buoys – or at least a substantial number of them – bob up and down in unison. This corresponds to a measurement of OGC. It represents an unusual occurrence in the context of this image because we do not expect the detailed motion of buoys (or waves) at distant ocean locations to be correlated.

There is no reason, *a priori*, to assume that the formal experiment, or equivalently, the statistic C1, captures all anomalous deviations present in the event data. While there is in principle an uncountable number of statistics we could investigate, the simple expression for C1 suggests a few forms to test.

First, and most obvious, is the value of individual trials, z_i, or more generally, the single trial moments of the form z_i^n which, taken together, represent the full statistical distribution of individual trials. We find that the single trial statistics conform to null behavior. This is an important result since it says that, within the accuracy of the experiment, direct perturbations of the individual trial scores are too small to measure. The formal experiment provides evidence of significant correlations among RNGs, but we do not see evidence of anomalous deviations in the trial values themselves.

Second, the C1 statistic suggests a class of correlation products, $z_i^n z_j^m$. A straightforward (albeit tedious) 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. This statistic is particularly interesting because it has exactly the same structural form as C1, but represents a unique, orthogonal correlation "channel".‡ The identification of C2 comes solely from analytical considerations, and it is not measured by the formal replication. As with C1, the average value of C2 is zero under the null hypothesis, and a positive value indicates the presence of correlations. A calculation of C2 yields

‡ Strictly speaking, the mutual correlation of C1 and C2 is identically zero under the null hypothesis. For convenience in calculations we employ a modified form which uses the pair-products of zero-mean quantities: *C2* = $(z_j^2\text{-}1)\,(z_j^2\text{-}1)$. Integer powers of C2 are also uncorrelated with C1, but not with C2 itself, so we need only examine the lowest order, C2. Details will be presented in a forthcoming publication.

an effect size of $\langle C2 \rangle = 3.8 \pm 1.8{\times}10^{-5}$. Interestingly, this is statistically indistinguishable from the C1 effect size. Details for the C2 calculation are shown in the last row of Table 1. Re-sampling analyses on the entire database empirically confirm to high precision that C2 conforms to null expectation for off-event data, and that C1 and C2 are uncorrelated.

Statistic	N	Mean value	Error	Deviation	P-value
Event Z-scores	280 events	$\langle Z_{event} \rangle = 0.31$	0.059	5.29σ	$0.6{\times}10^{-7}$
C1	$1.3{\times}10^{10}$	$\langle C1 \rangle = 4.25{\times}10^{-5}$	$0.88{\times}10^{-5}$	4.85σ	$6.2{\times}10^{-7}$
C2	$1.3{\times}10^{10}$	$\langle C2 \rangle = 3.79{\times}10^{-5}$	$1.74{\times}10^{-5}$	2.18σ	0.015

Table 1. Comparison of Z-score and correlation formulations. Row one gives the statistics for event-based analysis. Row 2 and 3 give trial-based statistics for the C1 and C2 correlations, respectively (see text). Columns show the number of events or trials, the mean, standard error, total deviation, and probability against chance.

In the image of ocean buoys, C1 corresponds to a correlation of the changing heights of distant buoys. A non-zero value of C2 corresponds to a discovery that the buoys are also correlated as they tilt from side to side.

Our characterization analysis thus finds that the RNG network exhibits two orthogonal trial-level correlation channels. The C1 statistic underlies the formal result, while C2 is revealed by analysis to be a unique, alternate correlation channel, not measured by the formal experiment. The finding that the two effect sizes are of the same magnitude is important for interpretations of the experiment. It suggests that global consciousness, when defined in terms of pair correlations, is a more general effect than is indicated by the formal experiment alone.

Figure 3 presents the two correlation statistics in the same cumulative deviation format used for the formal event Z-scores. They both show approximately the same slope, corresponding to their roughly equal effect sizes. Note also that C2 has a greater intrinsic variance than C1. This is visible in Figure 3 and shown in the Error column of Table 1. The C2 variance leads to a smaller significance level for the C2 statistic, relative to mean expectation.

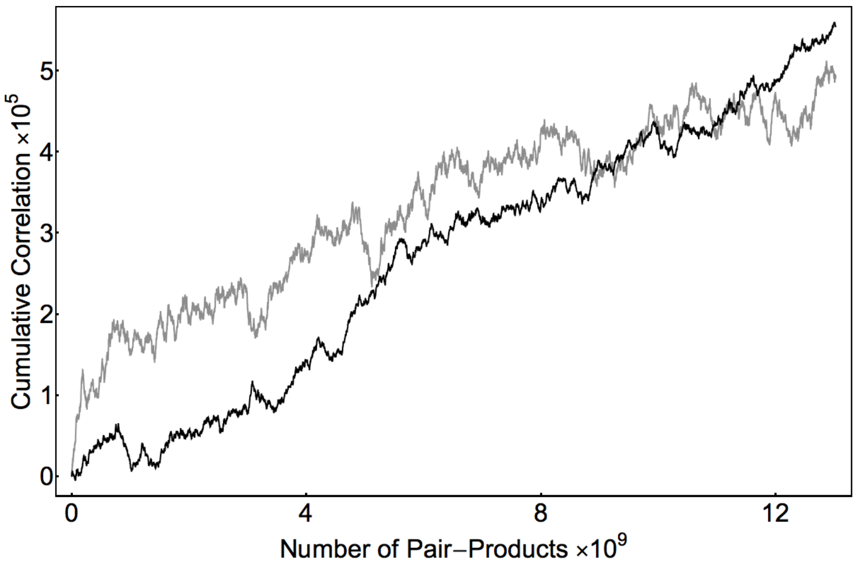

Figure 3. Chronological cumulative deviation from expectation of two measures of correlation in GCP event data. Black (lower) curve is C1. Gray (upper) curve is C2. Statistics related to C1 and C2 have been referred to in previous publications to as the netvar and covar, respectively.

Spatial and Temporal Structure

So far, we have shown that operationally defined global consciousness, OGC, corresponds to correlations in the RNG network, and that independent correlations also appear in a parallel channel. We would like to know if the event data contain further structure and if the structure might relate C1 and C2 more directly. 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 since the correlation statistics contain the RNG locales and trial times as parameters.

The GCP hypothesis anticipates structure of this kind because it posits an effect that is both dependent on the timing of events and geographically diffuse. Our general analytical strategy is to approach issues like these with as little theoretical overlay as possible. In this section we describe tests of structure in C1 and C2 which are based on minimal, physically intuitive assumptions about the effect. The tests yield positive evidence for spatial and temporal structure in the event data and illustrate the utility of our two-stage research strategy.

An immediate challenge is the choice of an appropriate measure for the tests. In the case of spatial structure, even events with a definite location, such as earthquakes or catastrophic accidents, lack a ready parametric description of the distribution of global reactions. Consider the terrorist attacks of September 11, 2001. Although the attacks occurred at three precise locations in the eastern United States, the response to the news of the event was widespread and complex. Moreover, it is not clear what aspects of the reactions pertain to OGC and how these might impact different regions of the network. Similarly, while the GCP hypothesis tacitly implies that effects will correspond to the event timing, it does not provide a metric for actual durations.

Despite these difficulties, both spatial and temporal structure are in principle detectable. Arguing from minimal assumptions based on the GCP hypothesis we can conclude that a characteristic of structure in the data correlations will be its smooth variation, both in time and across the network. These smooth, large-scale heterogeneities in the data are detectable signatures of OGC because they are not characteristic of excursions which occur purely by chance.

In the case of spatial structure, a test can be devised from a linear regression of the correlation strength against distance. The test avoids the issue of defining an event's location by considering only the distance between RNGs. A general observation from the physics of spatially distributed complex systems is that correlations among interacting constituents tend to weaken as their separation grows. Thus a prediction based on physical intuition suggests that the correlation strength will decrease as a function of RNG pair separation. A test of this conjecture is constructed as follows.

The geometrical separations of the RNG pairs are calculated for each of the 10^{10} elements of C1 in the event data. The elements are sorted by distance into bins (in the presentation below, the bin widths are 250 km). The average values of the correlation strengths are calculated for each bin, and a regression of correlation against distance is performed. A non-zero regression slope provides evidence of smoothly varying spatial structure, and the expectation is that the slope will be negative. The broad deployment of the GCP network allows us to perform the test over distances which range from a few meters out to the earth's diameter.

We find that a linear regression of C1 versus pair separation yields a negative slope, consistent with the prediction. The Z-score of the slope parameter relative to the null hypothesis is ~1.9, for a P-value of 0.015. Here, the null refers to a situation in which anomalous correlations are distributed homogeneously throughout the network. This would result in a complete lack of distance structure and a zero slope parameter in the regression analysis. The negative slope of the regression fit gives a zero intercept at a distance of roughly the earth's diameter, indicating that the correlations decrease gradually with pair separation, and that RNG pairs correlate over thousands of kilometers. Permutation and re-sampling analyses show that the distance structure does not occur for off-event data and that it is not due to an accident of the network geography.

The correlation C2 permits a similar, independent check of the distance structure. We find that a regression on C2 also yields a negative slope, with Z ~ 1.85 and a comparable range of decrease. The C2 regression lends additional support to the evidence for distance dependent correlations. It also suggests that C1 and C2 exhibit not only correlations of comparable strength, but that they share details of spatial structure. A joint regression of C1 and C2, shown in Figure 4, results in a slope parameter with Z ~ 2.8 (P-value 0.003).

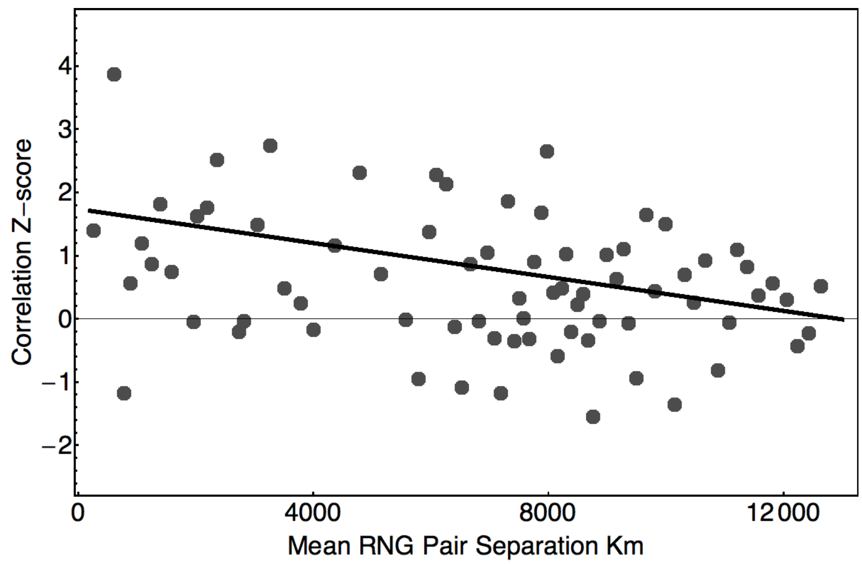

Figure 4. Regression of correlation strength on distance for a composite of the two measures, C1 and C2. The huge numbers of correlations are averaged in 250-km bins. The heavy black line is the fitted linear regression. A test of the negative slope parameter against the null yields a Z-score of 2.8.

The regressions give empirical evidence for spatial structure and indicate that models will need to incorporate distance-dependent correlations in order to adequately describe the event data. The form of the dependence (linear, exponential, etc.), and whether the dependence applies to OGC uniformly or only for certain kinds of events, are issues that remain to be resolved. These are challenging questions for analysis, as the weak effect size evident in the scatter in the plot of Figure 4 attests. However, simulations of a numerical model demonstrate that a linear dependence does provide a good initial representation of the data. Specifically, we model the distance dependence by a pure linear decrease which declines to zero at the earth's diameter. The simulation takes the measured total OGC correlation as input and returns the distribution of expected model slopes. The left-hand plot in Figure 5 shows the model, which exhibits a distribution that is well distinguished from a null model with distance-independent correlations (right). The vertical bar in the figure shows the slope value for the actual event data, which agrees with the linear slope model, but is incompatible with a null model that excludes distance dependence.

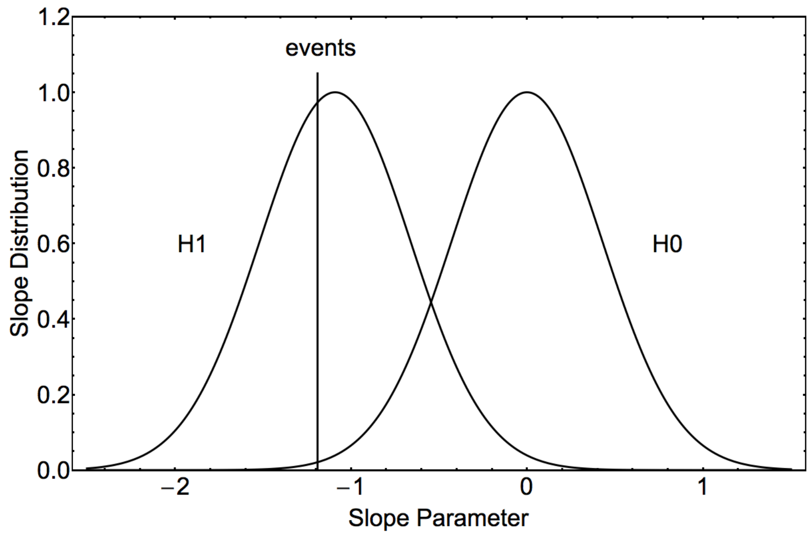

Figure 5. Model of the combined regression of C1 and C2. The left-hand curve shows the distribution of regression slopes for a decline in correlation strength which is linear in the RNG pair distance (H1). The vertical line indicates the actual regression slope for the event data. The right-hand curve plots the distribution of slopes for the null hypothesis (H0) of OGC correlations without distance structure.

For the analysis of temporal structure, we propose that the OGC correlations correspond to the human response to events, which first grows as an event becomes the focus of global attention, then persists for a time as people attend to the focus, and finally dissipates as attention wanes. The actual event data are likely to incorporate sections of null data before or after the correlations 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 characteristic of event data will thus be substantial periods of correlation during to the actual effect, bracketed by extended null sections (see Figure 6). The straightforward, yet non-trivial assumption we make is that temporal variations of global attention will correspond to time variations of OGC deviations.

The time structure can be tested by examining changes in the variance of the data. The test is constructed by concatenating all events into a single data vector which is then divided into time blocks of equal length. The variance of each block is calculated, and these are averaged to yield a "block variance" for the data set. Repeating this calculation for a range of block sizes gives the variance as a function of block length.

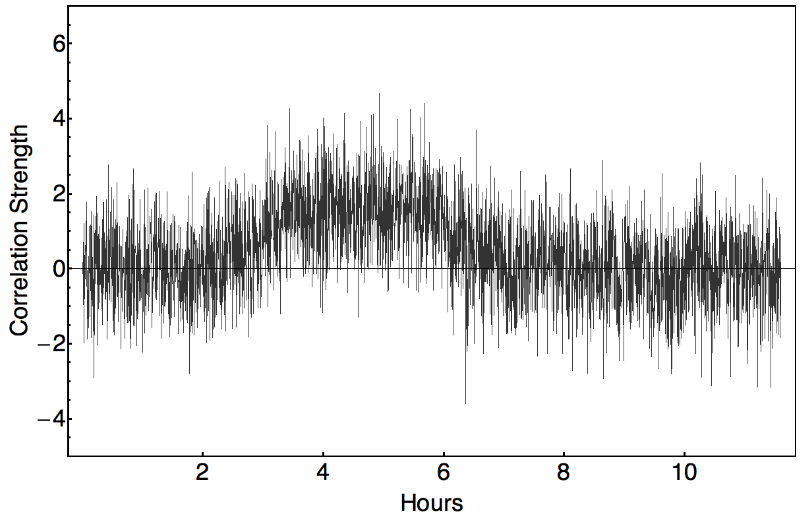

Figure 6. An exaggerated schematic of possible time structure. The intrinsic variance is constant throughout. An "effect" is shown extending from roughly 3 to 6 on the schematic time scale.

The temporal feature shown in Figure 6 leads to an increase in the block variance, and this can be employed in a statistical test for time structure. To see this, consider the total variation within a single data block. In the absence of an effect, the block's variance is determined by the intrinsic fluctuations of the random data alone. (For example, see the right half of the plot in Figure 6.) A similar result will obtain if a deviation is present in the data, but evenly (homogeneously) distributed throughout. However, for deviations which alternate with null periods, data blocks can straddle the cross-over region between deviating and null data sections. For these blocks, the change in deviation within the block will make an extra contribution to the block variance. When the block length is small, the excess contribution to the variance is small. As the block size approaches the length of the deviations, the excess contribution is more substantial and the block variance increases. The expected behavior in the presence of the proposed time structure is thus a block variance which rises smoothly to a maximum value and then levels off. The block length at which the variance attains its maximum value gives an indication of the time-scale of the effect.

Figure 7 plots the excess block variance of C1 versus block length. The experimental trace (in bold) exhibits a gradual rise to a maximum at about four hours, consistent with the expected behavior in the presence of OGC time structure. This suggests that correlations typically persist on this time-scale. The robustness of the calculation has been extensively checked with pseudo-random and re-sampled data. However, the confidence level is modest due to the low power of the test, which is limited by the intrinsic variance of C1. This can be seen by comparing the block variance calculation with a specific simulation model. Applying again the approach used for the analysis of distance, the total correlation of the event data is taken as input to a model. The predicted time structure is simulated by distributing the correlation into time blocks interspersed with null data periods. To keep the model simple and definite, the correlations are distributed into 3-hour periods. The block variance is computed for 1000 simulations, yielding the average variance for the model (gray curve, Figure 7). The low power of the test is evident from the size of the error bars in the plot. The simulation lies within two experimental standard deviations of zero, indicating that the power is limited by the amount of event data available for analysis.

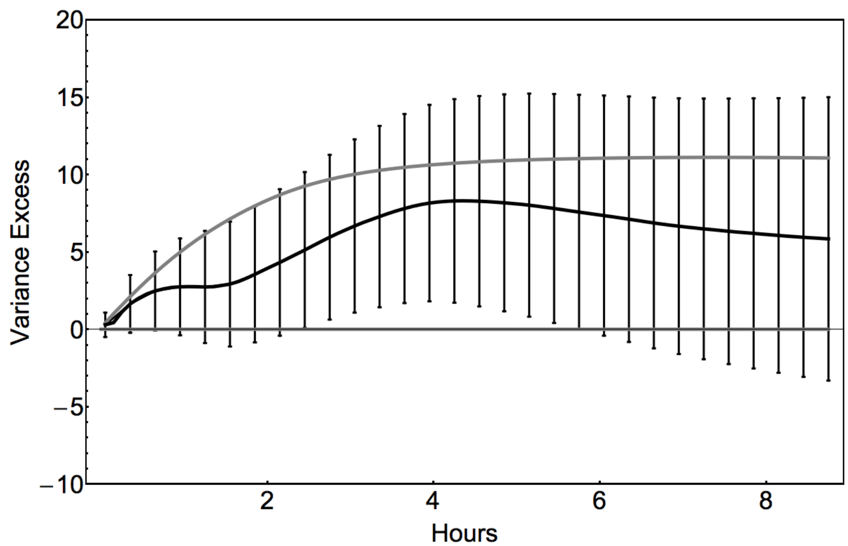

Figure 7. The heavy, black trace shows the excess block variance of C1 as a function of block size. Error bars show the 1σ uncertainties. The gray trace is a simulation of the same function, with the correlation data concentrated in randomly placed 3-hr blocks, interspersed with null data. The horizontal line at zero is the expectation for null time structure.

The block variance of the event data agrees with the model to within one standard deviation and yields a time-scale of several hours. These results are consistent with our intuitive expectations for OGC time structure, but this preliminary conclusion will need additional confirmation from refined or independent analyses. As in the case of distance structure, the temporal test can be applied independently to the C2 statistic. However, a simulation for C2 shows that the greater intrinsic variance of this second correlation completely dominates the test, rendering an assessment of time structure in the C2 statistic untenable. We are working to develop more powerful tests to overcome these limitations.

Models and Theory

We have demonstrated the existence of unexpected correlations and structure in the event data, and these results can serve as input for theoretical models of the deviations. To the extent that models are successful, they will not only describe the empirical findings, but will also refine our understanding of the structure and lead to testable predictions. Ultimately we seek a theory that provides a bridge from the empirical findings to a deeper understanding of the role mind or consciousness plays in the material world.

In keeping with our empirical and operational approach, we consider a variety of explanatory directions. For example, models might attribute the measured effects to:

1. Methodological errors or leaks which bias the formal replications
2. Conventional perturbations of RNG output due to ambient electromagnetic (EM) fields
3. A fortuitous selection of events and parameters through experimenter intuition
4. Retroactive information from future results determining the character of present data
5. A field represented as a linear superposition of individual human minds
6. An emergent field arising from a dynamical interaction among minds

The list is not exhaustive, but it spans a range of ideas from conventional approaches to speculations which explicitly attempt to include consciousness. These represent classes of models to investigate as we move forward. Let us consider each of the proposals briefly, asking how well they might address the anomalous data correlations.

Explanations of the formal experiment based on spurious effects can be rejected for the reasons detailed in the discussion of the GCP research program. Methodological leaks and systematic biases are precluded, respectively, by the event specification procedure, which effectively blinds the analysis, and the re-sampling controls which find no evidence of biases in the off-event data.

Proposals based on electromagnetic perturbations are among the most frequently advanced conventional explanations of the GCP results. However, such proposals 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. Lastly, direct analysis shows no evidence of diurnal variation in the RNG outputs, whereas ambient electromagnetic fields arising from the daily cycle of human activity would presumably induce a corresponding variation in the data. It should be emphasized that, while we do not see current proposals based on EM fields as viable explanations for the measured global correlations and data structure, it would be premature to exclude entirely the possibility of subtle EM effects.

The third and fourth proposals, intuitive selection and retroactive information, are variants of a theoretical position from parapsychology which has been advanced to explain psi functioning.[20-22] 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 choice of timing rather than an actual change in the data. The measured anomalies are attributed to the selection of data excursions in a naturally varying sequence. The fortuitous selection is assumed to derive from the experimenter's intuition, which informs the choice of events, their timing and the test procedures.[23] The C1 data deviations have been analytically tested against an explicit version of this model.[24] The tests nominally reject the proposal, but at present are not sufficiently powerful to draw definitive conclusions. However, these preliminary conclusions are supported by the model's failure to accommodate the spatial and temporal structure found in the data.

The retroactive information idea in proposal four is based on time symmetry arguments.[22] It proposes 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 and, like the selection proposals, they cannot easily explain the varieties of structure seen in the event data.

The last options propose two distinct field-type models associated with human consciousness. Proposal five bears a similarity to models based on conventional fields 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, while the field dynamics, which explain the RNG correlations, derive from the coherence of human activity during events. The proposal can accommodate the inter-node correlations and structure seen in the data, but it remains phenomenological since it does not explain how the field arises in terms of underlying principles.

The final proposal suggests that individual minds are mutually interactive. In this view, interactions among the minds of individuals are responsible for an emergent field or property which 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. The proposal can be construed as embodying in a formal way the ideas of such thinkers as Teilhard de Chardin[25] or Arthur Eddington.[1] While it represents possibilities that are likely beyond the reach of our current scientific tools, continued analysis of the GCP data will help us to determine whether we need to look to proposals of this type for an adequate explanatory theory.

Discussion

Our overview of modeling demonstrates that proposals need to be examined for consistency with the data structure. It is clear that current proposals either fail to explain the experiment or need further development to produce strong tests. At the same time, the diversity of approaches highlights the value of our empirical stance. Typically, theory and experiment work together to guide and advance research. However, the interplay between theory and experiment breaks down when experimental hypotheses lack a well-developed theoretical basis. This is evidently the case for the GCP event experiment, despite its robust 5σ result. From this point of view, OGC 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.[26] 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.

We have followed this strategy by adhering to an operational definition of global consciousness. The search for data structure has produced key results that will help to determine which classes of model are more likely to be viable. For example, preliminary assessments indicate that a phenomenological field model can in principle accommodate all the structure we measure: C1, C2, and the time and distance parameters, while models based on selection or on EM interactions face serious challenges.

More fundamentally, the empirical results lay the groundwork for a progressive investigation of the hypothesis and of OGC, which we summarize in the three questions below. We have partial answers to two of these questions, and future research will test and elaborate our provisional conclusions. Two distinctions frame the discussion. The first addresses whether the measured deviations are natural fluctuations or are due to changes in the behavior of the RNG network. We name an effect *physical* in the latter case. Second, we ask if an explanation of the effect requires new theoretical principles. We refer to an effect of this kind as *anomalous*. With these distinctions in mind, we can state three questions which will guide our thinking:

1. Is the effect physical?

Our provisional answer is yes. An effect that does not alter the RNG behavior must result from the fortuitous selection of naturally occurring data segments. But we have argued that models based on selection bias, whether from intuition or methodological flaws, are unlikely. A caveat is that our arguments, which rely in part on the evidence for data structure, are limited by the power of the statistical tests we employ. We are devising more powerful tests to address this limitation. It should be noted that intuitive selection can account for any structure in the data when models are open-ended, or not fully specified. However, the models then risk becoming teleological propositions about the data, without predictive status, and are problematic for their lack of closure and parsimony.

In addition, a physical basis for the effect is indirectly supported by the character of the data structure. The tests of temporal and spatial structure, as well as the C2 correlations, derive from simple, straightforward physical and analytical considerations, and are not the result of an unconstrained search for statistical excursions.

2. Is the effect anomalous?

Our provisional answer is again, yes. Models based on conventional physical causes such as EM fields must explain how the RNG shielding can be circumvented and why effects are not seen in off-event data, where the quantity of data augments the sensitivity of tests by an order of magnitude. A model might propose that ambient fields increase during events due to exceptional telecommunications activity, for example, but the OGC correlations are synchronized over thousands of kilometers (the mean RNG pair separation of the network is ~ 6500 km). Surges in ambient field amplitude may cover large regions, but such fields will not be coherent. Surge fields during events would thus generate unsynchronized data correlations, contrary to what is measured for OGC. The synchronization of correlations is both a strong argument against conventional proposals and a challenge for any detailed model of an anomalous effect. Accordingly, we continue to refine the data characterization, and particularly the timing of correlations, since this factor will play a key role in model building.

3. What characterizes an event?

With the data characterization in hand, an important next step is to undertake a similar analysis for the events. The goal is to define more precisely the criterion of "collective attention or emotion," and thereby provide a basis for distinguishing event characteristics that underlie the effect. As with the structure analyses, the approach is empirical and begins with general considerations. For example, the events can be classified into different psychological and sociological categories, and the categories' relative importance for OGC can be tested. One early study has shown distinctions among event Z-scores when the events are sorted by emotional type.[27] Analyses like this can now be augmented to include tests for data structure. An important question of immediate interest is whether different types of events have discernibly different signatures in the data.

Conclusions

The thing that doesn't fit is the thing that is most interesting.

-- Richard Feynman[28]

The GCP is a long-term experiment that asks fundamental questions about human consciousness. Our review describes evidence for synchronized effects of collective attention on a world-spanning network of physical devices. Careful analysis reveals multiple indicators of anomalous data structure which are correlated specifically with moments defined as important 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.

Although we are still in the early stages of the full research program, substantial progress has been made in understanding the GCP replication experiment. The analysis of data structure allows us to begin discriminating between theoretical approaches, and it provides tools for the essential job of refining our general hypothesis. To this end, our next efforts will emphasize the human and participatory aspects of OGC events.

We have argued that the GCP experiment is not easily explained by conventional or spurious sources and provisionally conclude that OGC is correlated with qualities or states of collective consciousness activity. While 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. These findings do not fit into our current scientific understanding of the world, but facts at the edges of our understanding can be expected to direct us toward fundamental questions.

It is important to consider different theoretical scenarios. Quantum entanglement, retrocausation, and other ideas have been discussed in this context, but these notions from physics have only tenuous connections to the GCP experiment, and it is currently hard to see an entry point to any physical model. Here, the Project's research provides much needed input by establishing parameters that may help discriminate models. For example, quantitative modeling can ask whether a linear composition of sources incorporating the known parameters can produce the field-like data structure, or whether a more complex model is needed.

More broadly, the GCP results are of relevance for the study of mind and brain because they bear directly on fundamental questions of consciousness. The starting point for much research in conventional brain science is: What are the neural correlates which give rise to consciousness? This question assumes that consciousness reduces to brain activity. The riskier starting point of the GCP is to ask: Are there correlates or a presence of consciousness to be found outside the brain? The question is highly challenging because it posits phenomena that are anomalous from a conventional standpoint. The search for neural correlates is unquestionably important for a comprehensive understanding of human consciousness. But the context and the meaning of that search changes completely if direct correlates of consciousness 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 explanation, after all, resembles a coherent, extended consciousness akin to Teilhard de Chardin's aesthetic vision of a noosphere? While this is a possibility beyond the supply lines of our scientific position, the experimental results are consistent with the idea that subtle linkages exist between widely separated people, and that consciousness is implicated.

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 may mean. One implication is that our attention matters in a way we may not have imagined possible, and that cooperative intent can have subtle consequences. This is cause for reflection about our responsibilities in an increasingly connected world. It is clear that our future holds challenges of planetary scope that will demand the full openness and clarity of science. On that, we will want to be of one mind.

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