

Independent Replication of an “Excess Correlation” Effect in pH between Isolated Beakers of Water

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Abstract

A preliminary independent replication was conducted using a magnetic field stimulation technique claimed to evoke “excess correlations” in the dynamic behavior of any two objects exposed to the same fields. The objects in this experiment were beakers of water separated by distances of one, six, or ten meters. Acetic acid was added to water in a “local” beaker while pH was simultaneously measured in a “remote” beaker in which nothing was added. Control tests involved either not adding acid to the local beaker in some runs, or by using a third beaker that was not exposed to the magnetic field. The prediction was that the remote beaker’s pH would shift toward alkaline during a specific phase of the magnetic field stimulation, as compared to the same measure in control conditions. Based on a linear mixed-effects analysis and a bias-corrected and accelerated nonparametric bootstrap procedure applied to 50 experimental and control runs a statistically significant ($p < 0.0005$) but small magnitude pH shift (+0.004) toward alkalinity was observed in the remote beaker during the predicted stimulation phase, supporting previously published claims.

Keywords

Excess Correlation, Magnetic Stimulation, Nonlocality, pH, Water, Linear Mixed-Effects Modeling

1. Introduction

The term “excess correlation” refers to anomalous entanglement-like correlations that reportedly arise between properties of physically isolated systems when both are exposed to a common sequence of magnetic field pulses at the same time,

which in practical terms means within a fraction of a second. Published articles describing such effects include pH shifts in water, seed germination, cell culture growth, photochemical reactions, human brain activity, and human behavior [1]-[18]. Two types of electromagnetic systems have been used to evoke such correlations: one with eight solenoids arranged in a circle to create a rotating magnetic field, and a simpler plastic-core toroidal system dubbed the “halo” [3] [19].

These reported effects are considered controversial for two reasons. First, while there have been many published reports of excess correlation effects, to date they have only been reported by researchers from Michael Persinger’s laboratory at Laurentian University in Sudbury, Canada. Second, the underlying physical mechanisms remain highly speculative. For example, one proposed explanation was that the correlations appeared to be analogous to quantum entanglement [20]. As an analogy that suggestion is acceptable, but the actual mechanism is unlikely to be quantum because decoherence effects in water and biological systems would preclude the presence of long-range or long-lasting entanglement [21].

Another proposal was based on the notion of nonlocal “informational fields,” which might mediate the observed correlations [22]. While interesting from a philosophical perspective, e.g., dual-aspect monism offers an expanded view of mind and matter that might be compatible with the existence of nonlocal correlations [23], these proposed explanations do not offer falsifiable physical mechanisms. Other hypotheses involved subtle electromagnetic field interactions or resonances that are said to arise between spatially separated systems, including shared environmental variables like geomagnetic fluctuations, Schumann resonances, or atmospheric noise [24]. Again, such ideas are plausible in principle, but the strength and range of the extremely low frequency and miniscule magnitude of the magnetic fields used in these experiments would not appear to be sufficient to account for correlations reportedly observed across tens to thousands of meters. Still other hypotheses were based on mathematical analyses of entanglement velocities for elementary particles in Minkowski space [15], and other arcane speculations.

From a conventional perspective, it seems more likely that the reported correlations were due to methodological artifacts or statistical errors. However, a notable lack of interest in empirical effects that resist conventional theoretical explanations appears to be the default in science [25], so no independent replication attempts have been reported. Sometimes anomalies turn out to be understandable in conventional terms, but if the anomalies resist mundane explanations, they might provoke a revolution. The only way to advance beyond the impasse is through replications, thus motivating the present study.

2. Methods

2.1. Hypothesis

When acetic acid from white vinegar is added to a “local” beaker of water placed in one halo, the pH of a “remote” beaker of water in a distant halo will shift toward

alkaline during a magnetic stimulation sequence known as the *effector* and not during a preliminary sequence called the *primer*.

2.2. Data Analysis

Samples of pH in each 30-minute test session were sampled at 1 Hz. To accommodate baseline variability and focus on temporal dynamics, each pH series was first normalized by subtracting the initial pH in each phase of interest (*i.e.*, primer vs. effector) from subsequent values to form ΔpH . A linear mixed-effects (LME) model, defined as $\Delta\text{pH} \sim \text{Time} \times \text{Phase} \times \text{Condition} + (1 + \text{Time} | \text{Trial})$, was used to analyze these data [26] [27], with fixed effects of *Time*, *Phase* (primer vs. effector), and *Condition* (experimental vs. control), plus random effects for intercepts and slopes to account for between-run variability and potential drift.

Based on this method, the analysis of interest focused on two outcomes: the main effect of *Condition* and the *Phase* \times *Condition* interaction. In the first case, the *Condition* factor compared the experimental (magnetic stimulation) vs. control (no stimulation) conditions to test the hypothesis that this difference would result in a positive ΔpH effect. In the second case, the *Phase* \times *Condition* interaction tested if the experimental and control conditions differed between the two temporal phases, with the *primer* vs. *effector* difference predicted to result in a negative ΔpH . Other factors, like *Time*, *Time* \times *Condition*, *Time* \times *Phase*, as well as the three-way interaction, would be of interest in future studies, but this replication attempt was specifically focused on evidence supporting the excess correlation claim.

Applying Akaike Information Criterion comparisons to alternative LME models indicated that including both *Time* and its interaction terms would improve the model's fit over simpler approaches [28]. Residual autocorrelations were planned to be checked with the Durbin-Watson method to assess if residual autocorrelations were acceptably low [29]. If autocorrelations were deemed high, which was not unexpected given the pH measures, then a BCa (bias-corrected and accelerated) nonparametric bootstrap method would be used to form 95% confidence intervals and adjust for possible autocorrelation biases, non-normal residuals, heteroscedasticity, and inflation of p-values [30].

2.3. Equipment

Each halo consisted of a 25.4 cm diameter plastic hoop wound with 225 loops of a 16-gauge copper wire. The wire ends were connected to an Arduino-driven microcontroller circuit (Figure 1). Although that circuit lacked a classic current return path through the toroid, the diode's junction capacitance allowed a weak displacement current to flow during each pulse, generating a small magnetic field (~ 20 nT) in the halo's center. When the halo was energized, the presence of the magnetic field was confirmed using a magnetometer (TriField Model TF2, lower AC range rated at 10 nT sensitivity, AlphaLab, Salt Lake City, UT). An amplified telephone pickup coil also produced an audible signal that matched the pulse sequences.

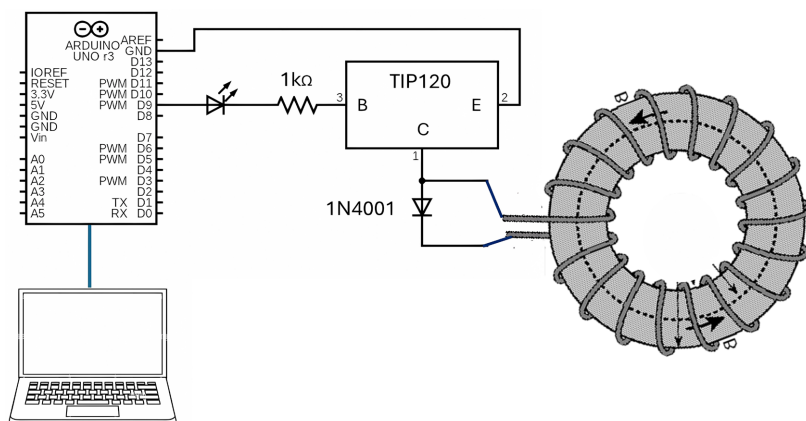


Figure 1. Arduino and electrical circuit used to energize the toroid. Short electrical pulses created a potential difference across the diode that allowed current to pulse through the toroid, in turn creating a weak magnetic field.

2.4. Protocol

Each Arduino microcontroller used to energize its halo ran a 30-minute program consisting of a 6-minute baseline period during which the electrical stimulation circuit was idle, then for 6 minutes it repeatedly generated the *primer* sequence, followed by 12 minutes running the *effector* sequence, and then ended with a 6-minute post-baseline idling period. At the middle of the *primer* sequence or start of the *effector* sequence several drops of acetic acid (~0.25 mL of white vinegar) were added to the local beaker. In some test runs acid was dropped once, and in other runs it was repeatedly dropped once a minute.

pH samples were time-stamped based on manually resynchronizing the Windows Network Time Protocol. The pH sensor was sampled at 1 Hz by a separate Arduino connected via USB to a Windows 11 PC (Atlas Scientific, Long Island City, NY, Model Gen3, resolution 0.001 pH).

Fifty experimental runs were conducted. **Figure 2** illustrates the experimental set up for the first 25 sessions, in which two 40 mL beakers were placed 1 meter apart and each was filled with 20mL of Fiji brand spring water (HCO_3^- 152, SiO_2 93, Ca^{2+} 18, Na^+ 17, Mg^{2+} 15, K^+ 5, Cl^- 11, SO_4^{2-} 2, NO_3^- 0.27, F^- 0.24; total dissolved solids (TDS) 222 $\text{mg}\cdot\text{L}^{-1}$ and pH 7.7) or tap water (chemical analysis unavailable). Each beaker was placed in the center of a halo, and both beakers and halos were placed on top of a 6 cm stack of plastic foam sheets on a plastic-topped table (to avoid magnetic distortions from proximal metallic sources). Each halo was energized separately, and the magnetic stimulation periods were manually started within a second of each other. In each beaker, a pH sensor (Atlas Scientific, Long Island City, NY, Gen3 pH sensor, resolution 0.001 pH) was placed and sampled at 1 Hz by an Arduino connected via USB to a Windows 11 PC.

For the next 15 tests, the beakers were placed in rooms 6 meters apart. For the following 10 tests, the beakers were again located 1 meter apart, but a single Arduino circuit was used to energize both halos simultaneously. In these runs, a third non-stimulated control beaker of water was placed between the local and remote

beakers. The final 5 tests placed the local beaker and halo 10 meters away from the control and remote beakers. The magnetic stimulation sequences in those runs were synchronized via a 901 MHz radio transceiver (Adafruit RFM69HCW, <https://www.adafruit.com/product/3070>). **Figure 3** shows photos of the various components used in these tests.

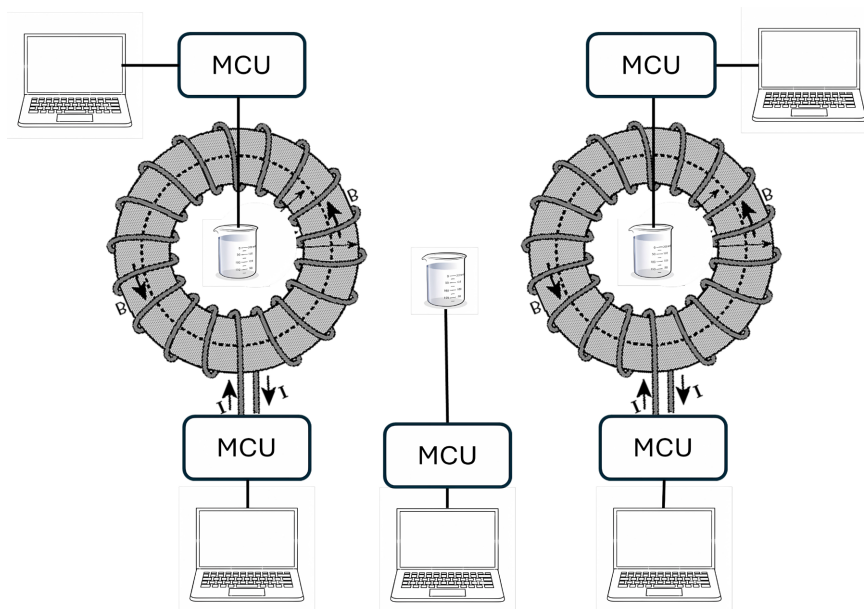


Figure 2. Illustration of experimental set up with two beakers subjected to the same type and timing of magnetic stimulation controlled by separate microcontrollers powered via USB (MCU, Arduino UNO r3). Separate laptops also recorded data from the MCUs that ran the pH sensors. For simultaneous control runs, a third beaker and sensor may be placed between the two stimulated beakers.

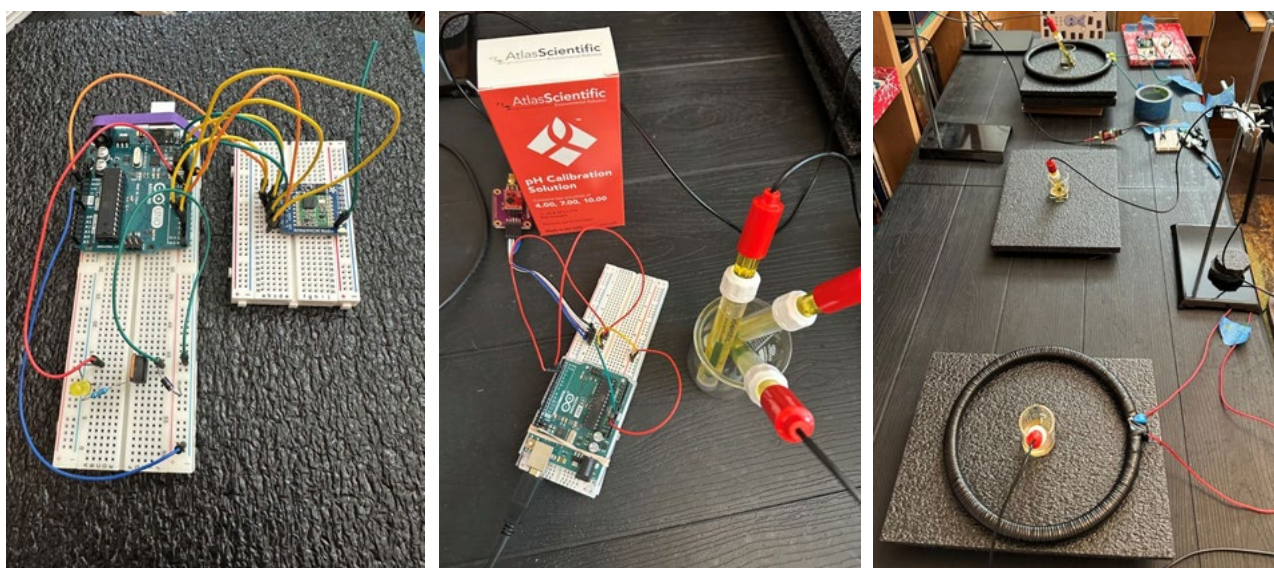


Figure 3. Left. Magnetic stimulation circuit combined with the radio transceiver used in the last 5 test sessions. Middle. pH sensor circuit and three pH sensors soaking in a conditioning solution. Right: Local and remote halos and beakers one meter apart, plus a central beaker used for control sessions, each with a pH sensor.

3. Results

3.1. Asynchronous Experimental vs. Control Tests

For illustrative purposes, **Figure 4** shows the results of two of 17 experimental runs. Notice that the remote beaker's pH displayed interesting inflection points near the moment when acid was added to the local beaker, with accelerated alkalinity shifts during the effector phase. **Figure 5** shows the results averaged across 17 experimental and 7 separate control runs.

LME analysis of these 24 half-hour sessions (17 experimental and 7 control) revealed a significant *Phase* \times *Condition* interaction ($p \ll 0.001$, see **Table 1**), indicating that ΔpH during the *effector* phase was significantly different from the *primer* phase. But the lack of a *Condition* main effect indicated no significant difference between experimental and control runs in the *effector* phase.

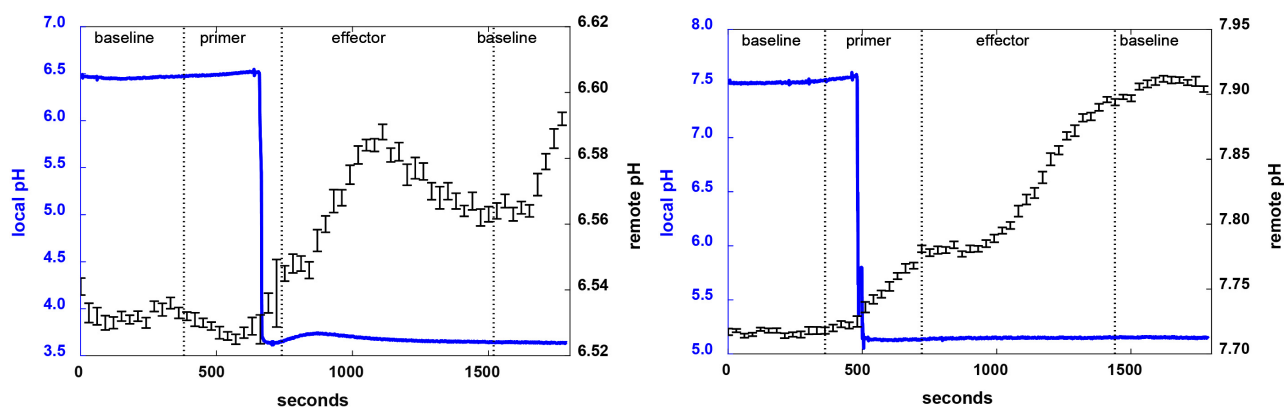


Figure 4. Examples of experimental runs where the local and remote beakers were 1 meter apart and the magnetic stimulation in each halo was controlled separately. The sharp drop in local ΔpH (blue line, left y-axis) indicates when acid was dropped into the local beaker. Error bars for the remote beaker curve are ± 6 standard errors calculated and displayed in 30-second segments (because 95% error bars would be too small to visualize).

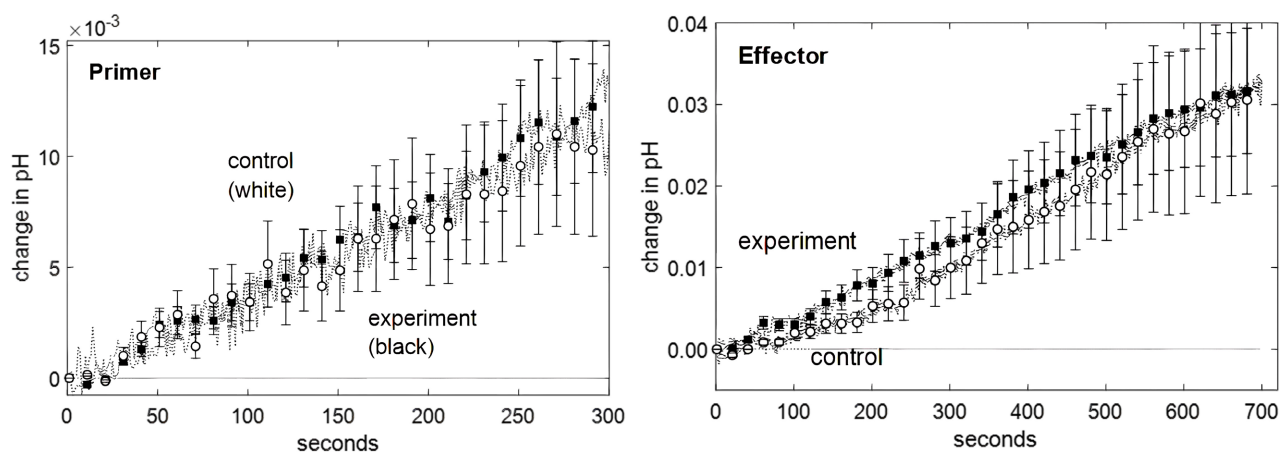


Figure 5. Mean pH across 17 experimental runs (acid added to the local beaker, black squares) and 7 control runs (no acid added to the local beaker, white dots) during the primer (left graph) and the effector (right graph) phases. Error bars are one standard error).

Table 1. LME results for independent experimental and control trials, with the statistical factors of interest highlighted in bold.

Term	Effect size estimate	SE	95% CI Lower	95% CI Upper	p-value
Intercept	-0.004	0.002464	-0.008984	0.000674	0.09
Time	0.000051	0.000022	0.000008	0.000095	*0.02
Phase	0.004	0.000384	0.003276	0.004781	* \ll 0.001
Condition	0.003	0.002927	-0.002746	0.008729	0.31
Time \times Phase	-0.000014	0.000022	-0.000017	-0.000010	* \ll 0.001
Time \times Condition	-0.000010	0.000026	-0.000053	0.000050	0.96
Phase \times Condition	-0.004	0.000456	-0.004485	-0.002697	* \ll 0.001
Time \times Phase \times Condition	0.000008	0.000002	0.000003	0.000012	*0.0006

*indicates statistically significant effects.

The mean Durbin-Watson statistic was 0.354, indicating strong autocorrelation in the Δ pH measures, as expected. Thus, the bias-corrected and accelerated (BCa) nonparametric bootstrap method was used to provide a more robust estimate for the confidence intervals and the actual p-values. That procedure produced the results shown in **Table 2**, which reduced the *Phase \times Condition* interaction to a nonsignificant $p = 0.111$. Thus, neither of the two main comparisons of interest showed significant results, but the effect size estimates were in the predicted directions, *i.e.*, a positive effect size of 0.003 for *Condition* and a negative effect size of -0.004 for the *Phase \times Condition* interaction. This outcome was promising but prompted a different approach for the second set of experimental tests.

Table 2. BCa bootstrap results and adjusted p-values.

Term	Effect size estimate	95% CI Lower	95% CI Upper	Estimated SE	Estimated p-value
Intercept	-0.004	-0.008157	-0.010233	0.001820	*0.023
Time	0.000051	0.000021	0.000090	0.000017	*0.003
Phase	0.004	0.000761	0.006861	0.001556	*0.010
Condition	0.003	-0.001671	0.007799	0.002416	0.213
Time \times Phase	-0.000014	-0.000061	-0.000029	0.000023	0.558
Time \times Condition	-0.000010	-0.000044	0.000036	0.000021	0.949
Phase \times Condition	-0.004	-0.007994	0.000852	0.002257	0.111
Time \times Phase \times Condition	0.000008	-0.000037	0.000057	0.000024	0.744

3.2. Simultaneous Experimental and Control Tests

To more rigorously control for possible environmental effects and to improve statistical power, 26 additional sessions were run wherein a remote and a control beaker were each measured simultaneously. **Figure 6** shows two representative

runs and **Figure 7** shows the average of all combined results, respectively.

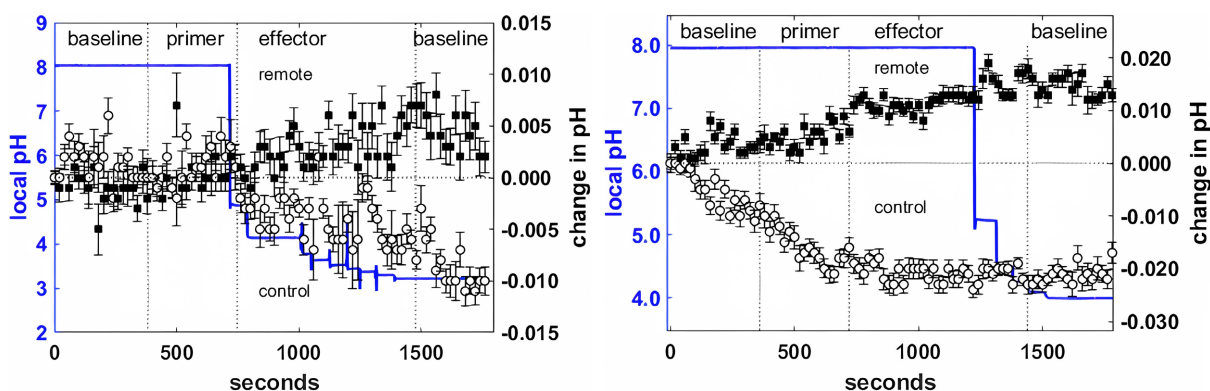


Figure 6. Examples of two experimental results with the local and remote beakers 6 meters apart, and with a third control beaker in between. The graphs show the remote ΔpH as black squares and simultaneously recorded control ΔpH in white dots. Error bars are ± 6 standard errors.

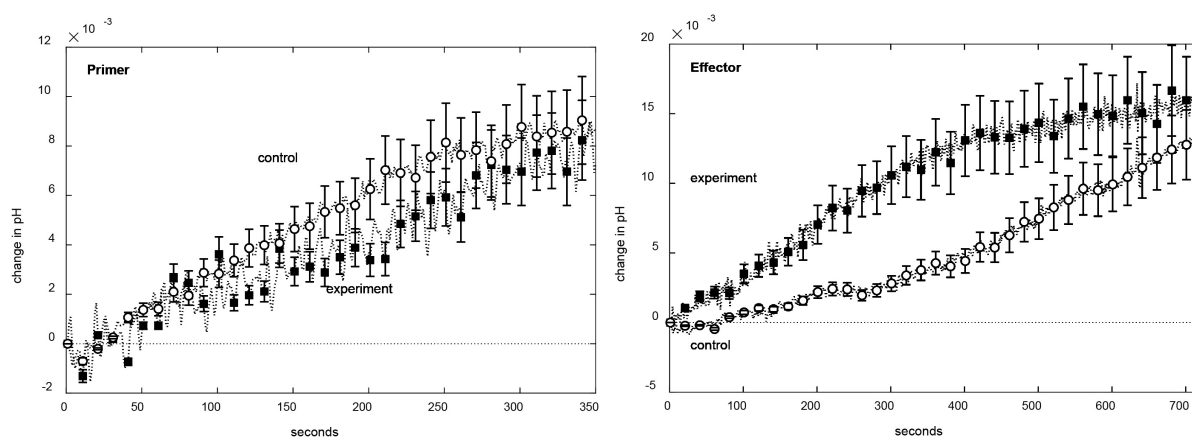


Figure 7. Combined results for mean ΔpH across 26 sessions with experimental results as black squares and control results as white dots. Error bars are one standard error.

LME analysis of these runs revealed a significant main effect for Condition ($p = 0.006$) and a significant *Phase* \times *Condition* interaction ($p \ll 0.001$) (see **Table 3**). However, the Durbin-Watson statistic again indicated excess autocorrelation in the ΔpH measures ($D-W = 0.296$), so the BCa bootstrap method was used to create a more robust estimate, as shown in **Table 4**. The BCa analysis indicated that the *Condition* and the *Phase* \times *Condition* effects remained significant and in the predicted directions, and the effect sizes were close to those observed in the first set of asynchronous tests.

Table 3. LME results for simultaneous experimental and control beakers.

Term	Effect size estimate	SE	95% CI Lower	95% CI Upper	p-value
Intercept	-0.001935	0.001037	-0.003967	0.000097	0.062
Time	0.000019	0.000007	0.000005	0.000034	0.009
Phase	0.002011	0.000153	0.001712	0.002310	$\ll 0.001$

Continued

Condition	0.004	0.001466	0.001133	0.006881	0.006
Time × Phase	0.000009	0.000001	0.000008	0.000010	≪ 0.001
Time × Condition	0.000003	0.000011	−0.000017	0.000024	0.745
Phase × Condition	−0.004	0.000216	−0.004903	−0.004057	≪ 0.001
Time × Phase × Condition	−0.000008	0.000001	−0.000009	−0.000006	≪ 0.001

Table 4. BCa bootstrap results and adjusted p-values.

Term	Effect size estimate	Estimated SE	95% CI Lower	95% CI Upper	Estimated p-value
Intercept	−0.001944	0.001167	−0.004220	0.000356	0.096
Time	0.000019	0.000005	0.000010	0.000029	* ≪ 0.001
Phase	0.002023	0.001289	−0.000585	0.004470	0.117
Condition	0.004	0.001426	0.001199	0.006789	*0.005
Time × Phase	0.000009	0.000008	−0.000006	0.000024	0.241
Time × Condition	0.000003	0.000008	−0.000012	0.000019	0.665
Phase × Condition	−0.005	0.001682	−0.007749	−0.001154	*0.007
Time × Phase × Condition	0.000008	0.000024	−0.000037	0.000057	0.744

4. Discussion

To assess the combined results of all 50 runs across the two experiments, Fisher's method was used to combine the BCa adjusted probabilities associated with the *Condition* effect and *Phase × Condition* interaction [31]. The result based on the four p-values (and Fisher's method of calculating df) was: $\chi^2 = 28.09$ (df = 8), $p = 0.00046$. Then, because the p-values derived for *Condition* and *Phase × Condition* in each study were not completely independent, Brown's method, augmented by Kost and McDermott's refinements, was used to take the within-experiment dependencies into account to calculate a revised combined p-value [32] [33]. That process resulted in a more significant outcome, $p = 5.27 \times 10^{-9}$, which can happen when the underlying tests contain a level of dependency that, when modeled appropriately, reveals stronger evidence against the overall null hypothesis. To be conservative, Fisher's method of combining p-values is used as the outcome of these experiments.

In sum, based on appropriate statistical techniques (LME, BCa nonparametric bootstrapping, and Fisher's method), plus consistent effect sizes observed across two experiments, it appears that these studies supported the hypothesis of excess correlation, bolstering the credibility of the previously published reports. It should be noted that those same reports suggest that the effect is sensitive to numerous controllable and uncontrollable factors, including the field strength generated by the halo, the specific magnetic sequences used, the quantity and type of water in pH tests, a claimed "space memory" effect, the orientation of the halos with re-

spect to magnetic North, and the Earth's geomagnetic field strength [34]. Such factors indicate that the excess correlation effect may not be strong enough to be easily observed under any conditions, but on the other hand, it was apparently robust enough to be discerned in the present studies without attempting to optimize those factors.

4.1. Limitations

While the results were statistically quite strong, the effect size ($\Delta\text{pH} \sim 0.004$) was small. The pH sensors used in this replication had a resolution of 0.001, and each sensor was calibrated several times using a standard three-point calibration procedure (Atlas Scientific calibration solutions, pH 4.00, 7.00, and 10.00, described as standardized against NIST-certified references), so they were in principle capable of measuring an effect of that magnitude. However, caution is advised when measuring an effect that is so close to a sensor's measurement resolution.

Another caution involves the low Durbin-Watson scores, because they raise valid questions about potential autocorrelated errors. The BCa bootstrap approach significantly mitigates such concerns, but future efforts might explore additional analyses that explicitly model autocorrelation, e.g., ARIMA structures or generalized least squares with autocorrelation corrections.

A further limitation is that on average both the experimental and control results exhibited a drift in pH toward alkaline. The rise in pH in the experimental sessions was predicted by the hypothesis, so that was not surprising. However, pH in control water exposed to air is expected over time to become more acidic, not alkaline [35]. This raises questions about the behavior of the pH sensors, or possibly it revealed an experimental confound called a "space memory" effect in a publication reported by Dotta *et al.*, and described as "...the 'memory' or representation of pH (H+) shifts remain in space long after the stimulus has been removed and can be retrieved within that space if the specific electromagnetic field is repeated" ([28], p. 511). If that reported memory effect was a genuine phenomenon, then the drift toward alkaline in the control beaker, which in some experiments was the same beaker but with fresh water, and in others it was a beaker in proximity to the remote beaker, might have been due to that effect.

In any case, despite the many successful replications reported by investigators in Persinger's laboratory, these claims will likely remain controversial because there are as yet no well accepted theoretical models to explain the effect. Conventional explanations include effects of fluctuations in ambient temperature, sensor drift, and other uncontrolled environmental artifacts. Unconventional explanations, as alluded to in the Introduction, have included quantum entanglement [6] [14] [19], "information fields" possibly mediated by ultra-weak magnetic fields [20] [36] [37], and "active information" as proposed by Bohm [38]. Another possibility involves longitudinal or scalar potentials, drawing analogies from the Aharonov-Bohm effect, wherein magnetic potentials can exert subtle nonlocal influences even without the presence of traditional EM fields [39] [40]. Also, collec-

tive coherence effects in water structure might underlie nonlocal coupling under certain conditions [41], and most of the systems tested using the magnetic stimulation technique involved water in some form.

4.2. Recommendations

The experimental setups used in these preliminary replications were straightforward, but a series of methodological enhancements may improve the reliability and credibility of the effect and also address potential confounds. Such improvements, in no particular order, could include:

- Automating acid injection into the local beaker via a robot fluid handler.
- Using blinding measures to ensure that some automated runs are experiments and others are controls.
- Testing water samples at various initial pH levels.
- Networking the microcontrollers to provide precise, unified timestamps for each measurement.
- Running experiments over many days to account for variation in geophysical factors.
- Frequently recalibrating all pH sensors.
- Performing all data logging directly on the microcontrollers.
- Automating data analyses from start to finish.
- Employing randomized delays or offsets in the magnetic stimulation start times.
- Testing multiple halos simultaneously to explore multi-site correlations.
- Adding ambient air and water temperature sensors.
- Changing the locations of the beakers on each experimental run to avoid the potential of a “space memory” influence.
- Preregistering study protocols and planned statistical analyses.
- Using a magnetometer with resolution of at least 1 nT to confirm the presence and strength of the magnetic fields created by the halo device.

5. Conclusion

This study successfully replicated a small magnitude but statistically significant excess correlation effect in water pH. Further independent replications are crucial to advancing our understanding of this potential nonlocal phenomenon. If it turns out to be a reliable effect, these phenomena may provide new insights into the nature of nonlocal connections.

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study are available to qualified researchers from the author upon request.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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