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PSYCHOPHYSICAL INTERACTIONS WITH PHOTONS: THREE EXPLORATORY STUDIES WITH UNEXPECTED RESULTS

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ABSTRACT

Interactions between focused mental intention and two properties of light (polarization and scattering) were studied in three exploratory experiments. To detect effects in polarization, a laser beam was passed through horizontal and vertical polarizers. Participants were asked to alternately focus their attention toward and away from the beam between the two polarizers. If attention affected the photons' plane of polarization, then the illumination intensity of the beam exiting the second polarizer should increase. Two experiments with different apparatus showed significant effects contrary to this expectation. To follow up on those results, a third experiment explored whether attention focused toward light would cause it to scatter (or refract, or be absorbed), resulting in a decrease in overall illumination. To test this idea, the intensity of a laser beam passing through a reflective sphere was recorded, along with any light deflected from the beam and ending up inside the sphere. The result was again contrary to expectation, with the light beam intensity significantly increasing after exiting the sphere. Interpretations of these results are discussed.

Introduction

Light plays an important role in the history of parapsychology (Fox, 2013). Reported experiences involving light include luminous phenomena perceived around magnets, gems, and the human body (Alvarado, 1987; Frodsham, 1978), luminous effects associated with physical mediums (Perovsky-Petrovo-Solovovo, 1945), the effects of "transforming light" (Puhle, 2014), cases of psychic photography (Eisenbud, 1979), tests of differences in psychokinetic effects performed in light versus dark environments (McMahan, 1947), tests of talented psychics to see if they could affect infrared light beams (Gregory, 1982; Gregory & Wilson, 1982), and the use of light as a psychokinetic target (Jeffers & Sloan, 1992).

Light continues to be an interesting object of study because photons are the quintessential quantum mechanical "entities", and as such experiments studying mind-matter interactions with photons might help to inform the numerous interpretations of quantum theory that have yet to converge to a consensus as to which is best (Sivasundaram & Nielsen, 2016). In earlier studies, we explored the role of conscious observation on the quantum wave-particle nature of light (Radin, 2008; Radin et al., 2012, 2013, 2015, 2016). In the present paper, we report on an investigation of two other properties of

photons: polarization and scattering. Polarization in this context refers to the way the electromagnetic components of light vibrate, somewhat analogous to the way that vibrations behave in a plucked string. This experiment was motivated by consideration of the Faraday effect (Atkinson, 2001; Bennett, 2005), in which the polarization of a photon can be affected by applying a magnetic field to a beam of light. The question we explored was whether a Faraday-like polarization rotation could be induced in photons by distant intention alone.

The scattering experiment followed up on the results of the polarization experiment (as described later), where scattering in this context refers to how a beam of photons can deviate from their original path, typically by interacting with charged particles (Lucas, 2005). This study investigated whether focused intention might act as a kind of "charge" that would affect the trajectory of the photons.

Method

Because the design of the two polarization experiments was similar, their methods and the apparatus are described first, and then the results of the two studies.

Polarization Experiments

Hypothesis

The hypothesis was that the vector angle of a photon's electric field, i.e., its polarization, would be influenced by mental attention focused on the beam while holding the intention to "twist" it. Note that by *attention* we mean restricting one's awareness to a specific location, and by *intention* we mean mentally willing a desired effect to occur at that location. If the hypothesized effect occurred, then the illumination intensity of the beam would increase after passing through crossed linear polarizers.

Apparatus 1 design

To test the hypothesis, we used an apparatus that passed a laser beam through crossed linear polarizers (see Figure 1). The first polarizer only allowed vertically polarized photons to pass and the second only allowed horizontally polarized photons to pass. The illumination intensity of the beam passing through the second polarizer was expected to be substantially attenuated, blocking almost all light from reaching the camera. However, if the photons traveling between the two polarizers were influenced by introducing a third polarizer (hypothesized to be achieved in this study by mental intention alone), then more light would pass through the second polarizer as a straightforward consequence of the vector nature of the electromagnetic field.

The optical apparatus was assembled on an Edmund Optics (Barrington, NJ) optical breadboard, which was in turn mounted inside a Zarges (Charlotte, NC) K-470 aluminum case, which was closed and light-tight while the experiment was running. The illumination source was a CrystaLaser (Reno, NV) 633 nm single longitudinal mode, linear vertically polarized, frequency and temperature-stabilized diode laser. The camera was a Thorlabs (Newton, New Jersey) LC100 2048-pixel Si CCD (silicon charge coupled device) line

camera. Other optical components, including the linear polarizing filters, optical posts and related hardware were purchased from Edmund Optics. The assembled apparatus, which weighed about 30 pounds (13.6 kg), rested on a 100 pound (45 kg) Herzan (Laguna Hills, CA) Onyx-7M vibration isolation table with pneumatic dampeners. A Panasonic Toughbook PC running Windows 7 was used to control the experiment and record the data. The experiment was programmed using Matlab (Mathworks, Natick, MA) version R2014b.

Protocol

Participants were asked to focus their attention toward the portion of the beam between the two polarizers, with the intention to mentally "twist" the beam at that point. One strategy used to accomplish this task was to imagine that the laser beam was like a taut string held by the thumb and index finger of both hands. During the focus-toward epochs, the light beam "string" could be symbolically twisted by having the thumb and finger of both hands rotate the string in opposite directions.

The measurement of primary interest was the illumination intensity of the laser beam as it passed through the second polarizer (**P** in Figure 1, top). This value was determined as the mean intensity recorded by the pixels at a predefined portion of the linear camera for the duration of each camera snapshot. The direct output of the laser (called the "standard" or **S** beam in Figure 1, top), was passed through a continuously variable neutral density filter (Thorlabs model NDL-25C-2) that was adjusted with a micrometer, so its peak intensity matched that of the P beam, and the illumination level of the beam passing between the polarizers (called the "bounce" or **B** beam in Figure 1, top) was also measured. The **S** measure was used as a baseline metric used to monitor drifts in laser power output due to changes in ambient temperature, vibration, and other environmental factors. The **B** measure was used to monitor the beam illumination before it entered the second polarizer.

Figure 2 shows the mean illumination levels recorded in the line camera across one session of 12,000 camera snapshots. The **S** metric for each frame was calculated as the mean illumination from pixels 100 through 275, the **P** metric was the mean from pixels 950 to 1200, and the **B** metric was the mean of pixels 1850 to 2048.The pixel ranges for each metric were determined empirically.

Apparatus 2 design

Experiment 2 was designed to replicate the first experiment in a newly designed apparatus. Rather than use a single line camera to record the **P**, **B** and **S** beams, in this study a Thorlabs DCC1545M monochrome camera was used to record the **P** and **B** beams, and a Thorlabs PM200 and S121C sensor were used to measure the laser power output **S**, as illustrated in Figure 3. The **P** and **B** illumination levels were the mean pixel intensities associated with those beams as recorded by the camera during each successive snapshot. In the latter case, the laser power output **S** was returned by the Thorlabs PM200.

The optical apparatus also employed a custom-built Arduino-based temperature control system, which was used to maintain constant

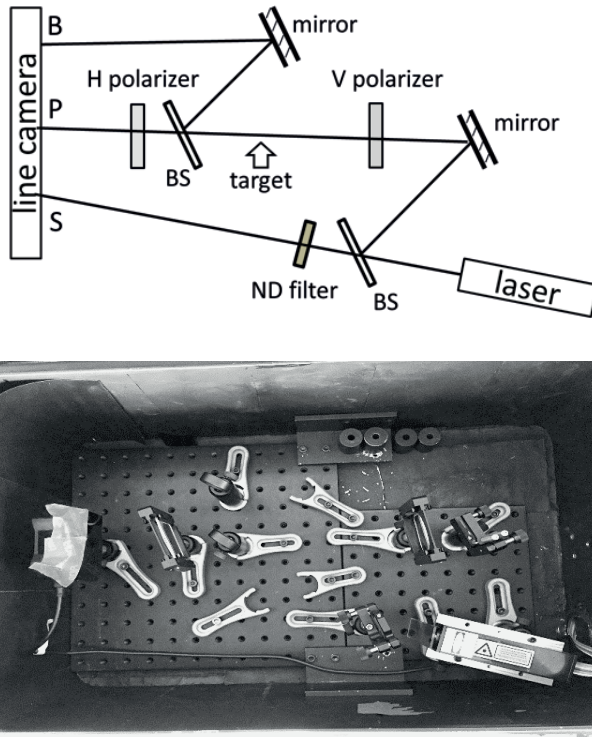


Figure 1. (Top) Apparatus used in Experiment 1. ND = neutral density. BS = beam splitter. The S ("standard") location on the line camera measured the laser power after passing through a neutral density filter adjusted to match the average illumination level of the P ("polarized") beam. The B ("bounce") beam measured the intensity of the beam between the vertical (V) and horizontal (H) polarizers. The intentional target area was the portion of the beam between the two polarizers. (Bottom) Photograph of the apparatus from above. Adhesive tape on top of the line camera was used to help to guide the cable connected to the camera.

temperature inside the Zarges housing. The experiment was controlled by a program written in LabView (National Instruments, Austin, TX) and run on an Alienware 17 computer (Dell Inc., Round Rock, TX) running Microsoft Windows 10.

Protocol

In Experiment 1, participants sat about a meter in front of the optically sealed apparatus. The controlling computer was located a half-meter away from the apparatus, on a separate table. During the experiment, a recorded voice announced, "Now please relax", which directed the participant to withdraw attention from the optical system, or it announced, "Now please concentrate", which directed the participant's attention toward the target area with intention to twist the laser beam.

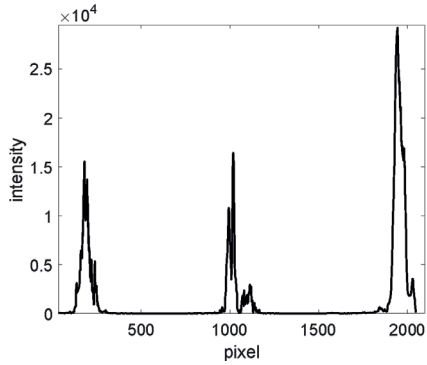


Figure 2. Mean illumination levels over 12,000 frames in a line camera with 2048 pixels. The left-most spike measured S, the "standard" laser intensity after passing through a neutral density filter to reduce the beam intensity. The middle spike measured P, the laser beam intensity after passing through both polarizers. The right spike measured B, the illumination of the beam between the two polarizers.

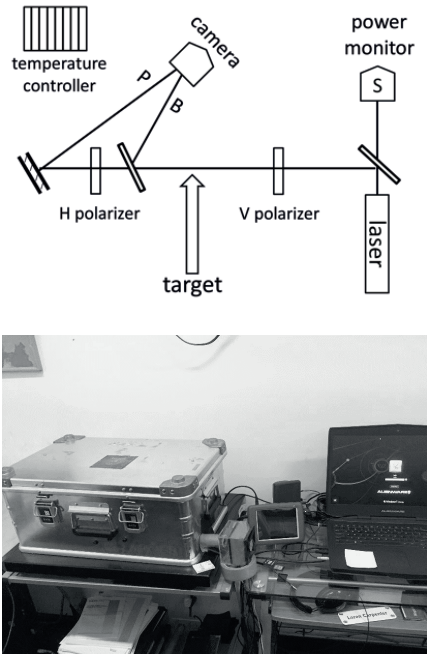


*Figure 3. Experiment 2 apparatus. (Top) The **S** or "standard" meter measured the laser power, the **B** or "bounce" camera measured the intensity of the beam between the vertical and horizontal polarizers, and the **P** or "polarized" camera measured the intensity of the beam after it passed through both polarizers. (Bottom). Photo of the experimental setup, with the optical system inside the shielded box at the left, and the controlling computer on the right*

Each attentional epoch was 30 seconds in duration, during which 20 camera snapshots per second were recorded by the computer. One experimental session consisted of 20 epochs, alternating between relax (withdrawn attention) and concentrate (directed attention) conditions, thus a total of 12,000 camera frames were recorded per session. Alternating conditions were used to avoid the possibility of randomly being assigned two or more 30-second concentration conditions in a row. Tasks that require focused attention to be held for more than about 30 seconds are difficult to maintain and encourage mind-wandering (Seli et al., 2016)but most of this research has not considered the potential importance of distinguishing between intentional and unintentional mind-wandering. However, a recent series of papers have demonstrated that mind-wandering reported in empirical investigations frequently occurs with and without intention, and, more crucially, that intentional and unintentional mind-wandering are dissociable. This emerging literature suggests that, to increase clarity in the literature, there is a need to reconsider the bulk of the mind-wandering literature with an eye toward deconvolving these two different cognitive experiences. In this review we highlight recent trends in investigations of the intentionality of mind-wandering, and we outline a novel theoretical framework regarding the mechanisms underlying intentional and unintentional mind-wandering.","container-title":"Trends Cogn Sci","DOI":"10.1016/j.tics.2016.05.010","ISSN":"1879-307X (Electronic, so we deemed use of a randomized condition sequence to be non-optimal for this type of experiment.

For feedback, during concentrate epochs, when the task was to direct attention toward the target beam and intentionally "twist" it, the computer drew a graph on a monitor that indicated the real-time illumination level of the polarized beam. During the relax epochs, when the task was to withdraw attention and intention from the beam, the graph remained blank.

The experiment was planned to consist of 15 such sessions. A matched set of 15 control sessions, used to test the apparatus, protocol, and analytical procedures for possible systematic biases, was conducted using the same apparatus and controlling program, and in the same location as the experiment, but without anyone present.

Experiment 2 followed a similar protocol, except that each test session consisted of 20 alternating "concentrate" and "relax" epochs, each epoch was 25 seconds in length, and 10 camera frames and laser power samples were collected per second, for a total of 5,000 samples per session. This experiment also added random inter-epoch periods of 1 to 3 seconds to decouple the epochs from potential cyclic behavior in the laser or environment; on average this added about 250 additional camera frames per session. The experimental phase of this study was planned for a total of 30 sessions, and the control phase consisted of 100 sessions. A larger number of control sessions were run to provide additional statistical power for detecting possible systematic biases. These two experiments were approved by the IONS Institutional Review Board (IRB# CARL_2015_01).

Analytical Procedure

To illustrate how the data were pre-processed, Figure 4 (top) shows how the illumination level for **S** in one session in Experiment 2 persistently

drifted up, regardless of the attentional assignments. Similar drifts were observed in the data collected in Experiment 1. The largest component driving this drift was likely due to variations in ambient temperature, which affected the sensitivity of the camera. To adjust for these drifts, a Savitzky-Golay third-order linear polynomial, with a window size of 10% of the sample length, was applied to each session's **S**, **B** and **P** signals (Savitzky & Golay, 1964). The resulting polynomial was subtracted from the original data, and the nonlinear residuals were used in the remainder of the analysis (Figure 4, second from top).

To adjust the **B** and **P** residuals for possible variations in laser power output (**S**), the **B**, **P**, and **S** arrays were each *z*-score normalized (call these $\mathbf{B}_z$, $\mathbf{P}_z$, and $\mathbf{S}_z$), and then $\mathbf{B}_z = \mathbf{B}_z - \mathbf{S}_z$, and $\mathbf{P}_z = \mathbf{P}_z - \mathbf{S}_z$. Analysis of the adjusted residuals indicated small autocorrelations between samples up to lag 3, so all data were down-sampled by a factor of 5. Figure 4 (bottom two graphs) shows a histogram and autocorrelation of the residuals after down-sampling. By inspection, the resulting samples appeared to be normal and independent, but to confirm that Durbin-Watson (Durbin & Watson, 1971) and Jarque-Bera (Jarque & Bera, 1980) tests were applied to these samples (Matlab functions *dwtest* and *jbtest*). Those tests confirmed that the down-sampled residuals conformed to parametric statistical assumptions, thus a two-sample t-test was used to compare means between the two conditions in each session.

Because the *t*-tests involved large degrees of freedom, the resulting *t* scores per session were distributed essentially as standard normal deviates (*z* scores). Those scores were combined over all experimental (and separately all control) sessions using the Stouffer *Z* method (Stouffer et al., 1949). The same analysis was then performed with the condition assignments lagged from –5 to +20 seconds to test the expectation that the cognitive load associated with switching attention between concentrate and relax conditions would take a few seconds, with the maximum results expected to be observed at a lag of +3 to +5 seconds (based on similar protocols in previously reported experiments, e.g., Radin et al, 2012).

Results

For Experiment 1, as planned 15 experimental and 15 control sessions were run, with all sessions contributed by the first and last author. Figure 5 (left) shows the results in terms of a Stouffer *Z* score for experimental sessions combined (black dots) and control sessions combined (white dots). No prediction was made for the **B**´ "bounce" measure, but the hypothesis predicted that the **P**´ "polarized" measure should increase if the laser beam's polarization was affected by the intention to twist the beam. Instead, both the bounce and polarize results were negatively correlated with the assigned intention, reaching peak values at lags of +10 to +11 seconds, then returning to baseline by lag +20 seconds. The data from the control sessions fluctuated around chance expectation for both the **B**´ and **P**´ measures.

Experiment 2 consisted of 30 planned experimental sessions, contributed by the authors and two other laboratory staff members, along with 100 control sessions. Figure 5 (right) shows that again both the bounce and

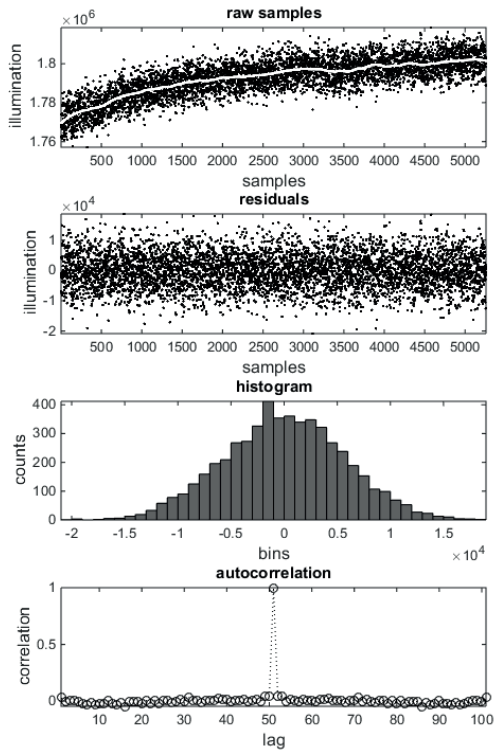


Figure 4. (Top) Illumination samples (black dots) and nonlinear fit (white line) in data from one session in the second experiment. (Second from top) Residuals produced by the difference between the samples and the nonlinear curve. (Third from top) Histogram of residuals. (Bottom) Autocorrelation of residuals.

polarized resulted were mostly negative. Control data were at chance for both measures.

Because multiple lags were explored in this analysis, the False Discovery Rate algorithm was used to adjust the 26 *z*-scores combined across the two experiments, as shown in Figure 6 (Benjamini & Hochberg, 1995). That result showed significant negative results (with alpha set to $p < 0.05$, two-tailed) for both the experimental **B**′ and **P**′ data starting at lag +4 and continuing for the next 11 lags. By contrast, none of the control comparisons were significant. Further discussion of these results appears in the "General Discussion" section, later in this paper.

Scattering Experiment

To explore the unexpected results of the polarization studies, a third experiment was conducted to investigate what might have happened to the "missing photons" associated with the decline in illumination. Unlike the first two studies, which primarily relied on the experimenters as participants, this study was planned for 40 individual participants.

Hypothesis

The polarization experiment suggested that mentally focusing on a beam of light while holding the intention to twist it caused its intensity to decline, contrary to the original hypothesis. If that decline were caused by scattering (for expository simplicity we refer only to scattering, recognizing that refraction or absorbance would lead to the same result), then while directing one's attention toward a beam aimed directly at a camera while holding the intention to mentally deflect the beam, then the camera should record less

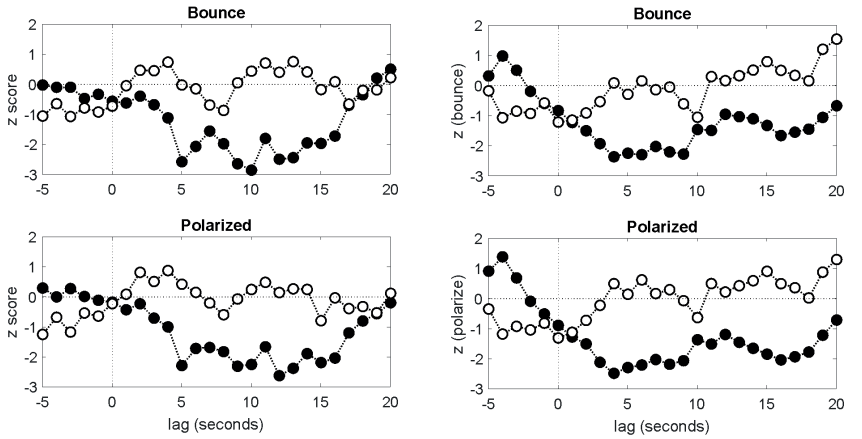


Figure 5. (Left) Results of first experiment (black dots) and control (white dots) for bounce and polarized illumination levels between concentrate and relax epochs, expressed in terms of a Stouffer Z score. (Right) Same analyses applied to the second experiment.

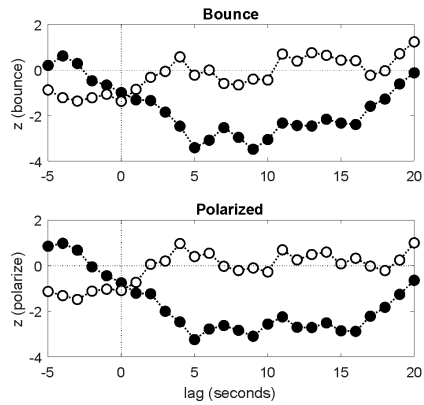


Figure 6. Results of first and second polarization experiment combined in the form of Stouffer Z scores. Adjustment for multiple comparisons showed that the experimental results (black dots) were significant at $p < 0.05$ from lags 4 through 15. None of the control results (white dots) were significant (before or after adjustment).

intensity as compared to when attention was withdrawn from the beam. In addition, while participants intended to deflect the beam a photodetector set up to monitor scattered light in the vicinity of the target area should presumably detect an increase in illumination.

Participants

Participants were selected from a pool of candidates in the San Francisco Bay Area through the website Craigslist.com, the IONS website (noetic.org), and recommendations from IONS staff members. Potential participants were screened by self-report via an online Google form to ensure appropriate enrollment according to the inclusion/exclusion criteria (Table 1). A research assistant contacted each potential participant by email or phone to confirm that they fit the inclusion/exclusion criteria. If they did, a recording session was scheduled, and then they received an email confirming the date and further instructions to prepare for the session.

Upon arrival, before starting the experiment each participant signed an informed consent approved by the IONS Institutional Review Board (designated "RADD_2019_01"). Then a research assistant provided the participant with the task instructions, answered any questions they may have had, then invited them to sit in a chair inside the IONS laboratory electromagnetically shielded chamber. That chair was located about two meters from the optical apparatus, which was also located inside the chamber. After completing the experiment, each participant received a paperback book as compensation for their time and efforts.

Table 1.

Inclusion and Exclusion Criteria

Inclusion	Exclusion
• Age 18 years or above • Able to maintain attention on a single task for at least 20 minutes • Meditation practice (at least 1 year of experience, and practice of at least once a week) • Able to remain in an enclosed 8x8 foot room for ~40 minutes • Can hear and understand instructions in English	• Younger than 18 years old • Difficulty remaining in an enclosed 8 × 8 foot shielded chamber for ~40 minutes • No meditation experience • Lack of normal vision or hearing • Cannot commute to laboratory • Cannot understand English

Apparatus

Key components of the optical system used in this experiment (see Figure 7) included: (a) a 10 cm diameter hollow steel sphere (King Architectural Metals, Los Angeles, CA) with holes drilled on top and bottom to allow a laser beam to pass vertically through the sphere; (b) Brewster windows placed on the top and bottom holes to allow the sphere to be sealed, but also allow the laser beam to pass through with minimal reflection losses, (c) a 632-nanometer red diode laser (Coherent LabLaser, 635 n, 5 mW, Santa Clara, CA) that passed a beam through a series of neutral density filters (ND4 illumination

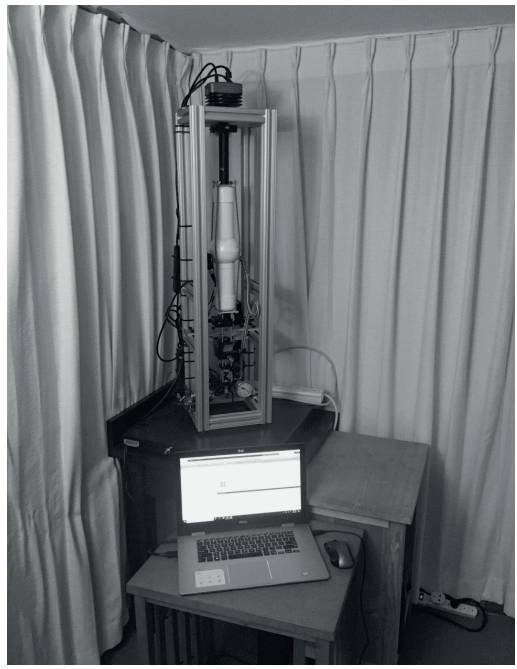


Figure 7. Optical apparatus used in the photon scattering experiment. See text for explanation.

reduction) and then through the sphere and into a (d) thermoelectrically-cooled monochrome CCD camera (Throlabs 4070M-GE-TE, 2048 × 2048 resolution); (e) a photodetector on one side of the sphere (ThorLabs PDA36A Switchable Gain Detector); (f) a "noise eater" device to reduce random variations in the laser's power output (Thorlabs NEL01); (g) a thermocouple to measure temperature inside the sphere, (h) an accelerometer used to detect vibrations on the apparatus, (i) a 45 kg vibration-isolation table used to dampen ambient vibration (Onyx series, Herzan, Laguna Hills, CA), and (j) a Windows 10 computer running a program in Matlab (version 2016b, Mathworks), used to collect data from the various sensors.

The interior of the steel sphere was spray painted with 10 coats of barium sulfate to create a 98% efficient diffuse reflective coating (Edmund Scientific, Barrington, NJ). The sphere's design provided uniform scattering of light such that light bouncing inside the sphere could be detected by the photodetector mounted in the sphere's wall regardless of its direction or origin. The barium sulfate coating inside the sphere resulted in an estimated mean of approximately 34 photon bounces before the photon was absorbed; this increased the sensitivity of the photodetector by a corresponding amount. Photons lost through the laser entry and exit holes at the top and bottom of the sphere reduced the sensitivity by a few percent. While the amount of light attenuation was expected to be quite small in magnitude relative to the total power output of the laser, any scattering would have presumably

increased illumination in the sphere, as measured by the photodetector. The laser beam was aimed so it passed directly through the sphere, with no light impinging on any intervening object.

The cooled camera continuously measured the illumination level from the laser beam. If the beam passing straight through the sphere were attenuated due to mental intention, then that would be detected as a decrease in direct illumination, which in turn should correlate inversely with scattered light detected by the photodetector located inside the edge of the sphere. These two measures therefore provided a way to simultaneously measure both the direct (straight-through) and scattering (or reflection or absorption) illumination intensities.

The computer continuously acquired samples from the accelerometer, temperature, photodetector, and camera. Data samples from the first three samples were recorded ~20 times per second, and snapshots from the camera were recorded once per second. All data were recorded once per second, including the camera snapshots along with the per-second mean values of the other sensors.

Protocol

One session consisted of 30 trials, alternating between 30-second epochs with instructions to concentrate attention toward or away from the laser beam as it passed through the sphere. Sessions lasted for 900 seconds (15 minutes), with each successive attention instruction announced via a recorded voice according to the assigned condition, i.e., either by the phrase "now please concentrate," meaning focus one's attention inside the sphere with intention to block or deflect the beam, or "now please relax," meaning withdraw attention from the sphere.

Immediately after each experimental session, a control session identical to the experimental session was conducted, except that the computer monitor was hidden from the participant by an opaque screen and the spoken instructions for each successive epoch were altered so they uniformly announced, "now please relax." Voice instructions were maintained during control sessions, even though they were always the same, to ensure that any ambient vibrations or electromagnetic fields produced by activation of the computer's speakers would be similar during experimental and control sessions. During control sessions participants were asked to remain seated and quietly read a book for the 15 minutes it took to complete data collection.

During experimental sessions, when participants were instructed to "concentrate" they attempted to mentally block the laser beam as it passed through the reflective sphere. To assist them in focusing their attention on this task, real-time visual feedback about the light intensity was provided. If the straight-through laser beam dimmed with respect to the prior sample's illumination level, a graphic of a vertical red rectangle displayed on the computer screen also dimmed. The goal then was to try to make the red rectangle progressively dimmer and whiter in color, which indicated that focused concentration was dimming the beam. If the beam illumination increased, then the red image became brighter and redder (the color red was used for the feedback because that was the color of the laser beam itself.)

This feedback was updated once per second. During relax epochs, the screen remained blank and no feedback was provided.

Analysis

Because this was a new, exploratory experiment, we did not have prior effect sizes with which to perform a power analysis. Thus, we pre-specified 40 experimental sessions, relying on the law of large numbers in hopes of providing enough data to detect an effect.

The optical measurements of interest were the laser beam illumination measured by the camera at the top of the apparatus, as well as the scattered light measured by the photodetector in the wall of the reflective sphere. The former measure was in the form of the sum of the illumination level of all of the camera's pixels divided by the number of pixels, 4,194,304 (i.e., the CCD size was 2048 × 2048). The camera took one snapshot per second. The photodetector, accelerometer and temperature data were each in the form of a voltage provided to the computer at 20 Hz via an analog-to-digital converter. These three values were each averaged (separately) to provide one mean sample per second.

Because the camera data on average exhibited a linear drift (in both the experimental and control sessions), as shown in Figure 8 (left), the camera data in each session were linearly detrended before further statistical analysis. The mean photodetector data showed a slight positive drift over the course of a session (Figure 8, right), so those data were also detrended.

Visual inspection of the average vibration data (Figure 9, left), in both experimental and control sessions, indicated that on average the first 30 samples exhibited greater variance than the rest of the session. This was probably due to the research assistant's movements while starting up each session and by closing the chamber's heavy steel door when he exited the room. Because of those vibrations, the first two attention instruction periods (a total of 60 samples) were excluded from further analysis to maintain an equal number of attention-toward and attention-away epochs. A small positive drift in temperature was noted in the temperature data (Figure 9, right), likely reflecting a rise in temperature inside the shielded room produced by body and equipment heat over the course of the session.

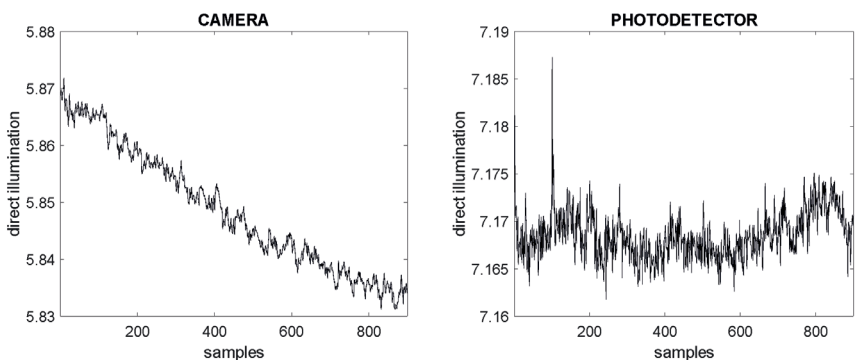


Figure 8. Average camera and photodetector measurements across all sessions.

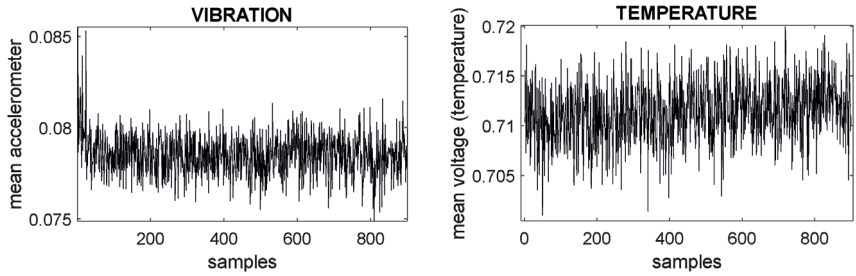


Figure 9. Average vibration and temperature measurements (in units of voltage as returned by the sensors) across all sessions.

To assess changes between the concentrate vs. relax conditions, the mean of all data in each session collected in each of the two conditions was compared using a randomized circular shift permutation technique. This procedure first calculated the mean difference between samples in the two conditions, then randomly circular-shifted the data and recalculated a new mean difference, then repeated this process 1,000 times. The final z score of the mean difference was calculated as $z = (D - m)/s$, where D was the original mean difference, and m and s were the mean and standard deviation of the randomly permuted differences, respectively. This approach is a useful nonparametric technique for assessing differences in autocorrelated data without making any assumptions about the sample distributions.

The same analysis was then conducted after lagging the condition assignments by one to eight seconds, each time producing a new result to compensate for the cognitive lag resulting from the tasks, which required shifting one's attention. It was expected based on previous studies that a delay of about 3 to 5 seconds would show the optimal effect, but because this was a new experiment, we enlarged the time window in case these effects corresponded to slightly faster or longer cognitive lags. A False Discovery Rate (FDR) correction for multiple comparisons was applied to the nine results lagged from 0 through 8 seconds to control for false positives. The FDR-corrected outcomes were considered statistically significant if they resulted in $p < 0.05$, two-tailed.

Results

Results shown in Figure 10 (left) indicate that when participants focused their attention and intention toward the reflective sphere, a rise in illumination was measured by the camera at the top of the apparatus (the straight-through measure), as compared to when attention was withdrawn (relax trials). At the same time, light reflecting around inside the sphere dropped. Of the 9 lags tested, lags 4 through 7 for the straight-through measure survived correction for multiple comparisons. None of the photodetector measures taken at the same time were significant, before or after adjustment. Figure 10 (right) shows that nothing remarkable occurred in the matched control sessions run immediately after the experimental sessions.

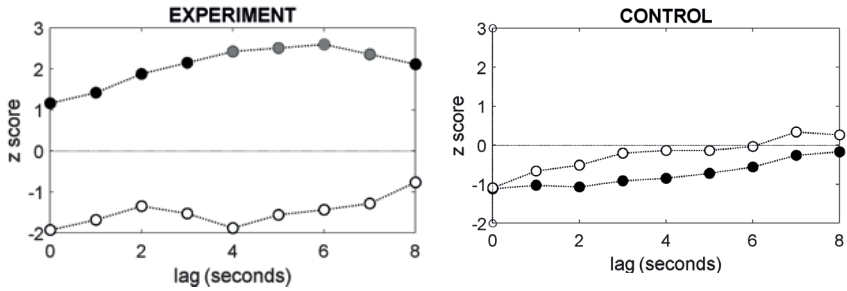


Figure 10. (Left) Experimental results. Black dots indicate differences in light intensity observed by the straight-through camera when comparing attention toward vs. away from the sphere. White dots show the same comparison for light detected by the photodetector inside the sphere. The grey dots at lags 4 through 7 were significant at $p < 0.05$ after FDR adjustment for multiple comparisons. (Right). Same descriptions for control sessions.

General Discussion

The results of these experiments suggest that our hypotheses about how mind and light interact, or perhaps the way that we went about testing those ideas, or both, were incorrect. In the first two experiments, we hypothesized that intention might be able to "twist" a beam as it passed through crossed linear polarizers, which in turn would have caused the beam intensity exiting the second polarizer to increase. Instead, we observed a significant decrease. The control tests in those experiments indicated no systematic apparatus or analytical biases that might have spuriously caused those results.

Based on those results, we guessed that perhaps focusing attention and/or intention toward a laser beam interfered with the beam in some way, reminiscent perhaps of anecdotal "cold spots" reported during ostensible poltergeist and haunting episodes (Andrews, 1977; Batcheldor, 1966). This idea led to the third experiment, which was designed to test if the photons from the first two experiments might have been deflected or absorbed in some way. But again, contrary to our hypothesis, we found that a laser beam passing through a reflective sphere, where the task was to intend to block or deflect that beam, resulted instead in a significant *increase* in intensity rather than a decrease. Carefully matched control sessions showed no unexpected effects.

As exploratory studies, it is unknown whether the same apparatus, procedures, and analytical methods would show the same results in follow-up replications. It also remains uncertain about exactly what was influenced. That is, the physical target in all three studies was nominally a beam of photons. But it is possible that one or more of the sensors or other aspects of the apparatus were influenced. For example, in the first two studies, a decrease in light intensity could have been due to enhancement of the light-blocking efficiency of each of the two polarizers, with nothing directly affecting the photons. Or, because the participants were also the investigators in those two studies, perhaps the observed results were idiosyncratic and other participants would have produced different outcomes. Likewise, in the third experiment the increase in light straight through the reflecting sphere might

have been due to mental enhancement of the efficiency of the straight-through camera, again with nothing else directly influencing the photons.

One important consequence of the surprising outcome of these studies is that they reduced the possibility that the results could be "explained away" as mere experimenter psi effects, or as goal-oriented effects (Kennedy, 1976; Schmidt, 1987). Expectation effects are well-established in conventional psychological studies (Rosenthal & Rubin, 1978), and they also seem to occur regularly in psi experiments, so when an experiment supports what the investigators are hoping to find, it is difficult to know if that means the original hypothesis was correct, or whether the data fortuitously conformed to the investigators' expectations (May et al., 1995; Varvoglis, 1986). Thus, outcomes that are significantly opposite to the experimenters' expectations provide useful clues that something about the way the questions were asked, or how the hypotheses were tested, were heading in the wrong direction. As such, unexpected results can be more informative than supportive evidence.

In considering future versions of the present experiments, one change we might recommend for the scattering experiment would be to revise the feedback, i.e., positive feedback should not be indicated by making a bright red rectangle become dimmer and whiter, but instead by using an image less likely to be misinterpreted, like a line on a graph that moves up. We say this because in our experience positive feedback is more naturally associated with brighter rather than dimmer colors, so it is possible that some participants misinterpreted the meaning of the feedback used in the third experiment.

In addition, more intimate and motivating feedback is desirable over the rather abstract tasks required by these studies. One approach to improving this kind of immediacy that is gaining popularity across many disciplines is the use of virtual reality (Cieślik et al., 2020). Devising a virtual experience that reduces the abstract nature of the mind-light interaction task, perhaps by including haptic feedback so the light beam can be physically "touched" in virtual space (Butt et al., 2018), may improve the experimental yield.

Conclusion

The studies reported here are part of a long line of experiments investigating the role of consciousness in the physical world (Jahn & Dunne, 1986; Pratt, 1960). In the present case, we used photons as the physical targets partially because of continuing interest in light phenomena within psi research, but also because photons are quantum "entities," and as such these types of experiments may help to inform questions about the nature of observation in quantum theory (Houtkooper, 2002; Myrvold, 2018).

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