

A Double-Slit Diffraction Experiment to Investigate Claims of Consciousness-Related Anomalies

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Abstract — An experiment in which participants were asked to reduce the fringe contrast in a Young’s double-slit interference pattern has been conducted independently at two laboratories using the same apparatus. Participants at York University were explicitly invited to exert their intentionality either to direct the photon flux preferentially through one path or the other, or to obtain spatial information about the division of the flux. Participants at Princeton University were invited simply to reduce the fringe contrast by any strategy they wished. Results from both laboratories ($Z = -0.481$ and $Z = 1.654$ respectively) are discussed along with a description of earlier efforts to frame this experiment as a test of an extra-sensory channel for the acquisition of information.

Keywords: Young — double-slit — diffraction — anomalies — human/machine interactions

Introduction

There have been many claims of successful demonstrations of anomalous perturbation of stochastic processes correlated with human intention (Radin & Nelson, 1989), although the mechanism underlying such anomalies is not known. The experiment reported in this paper was originally conceived as a means of testing whether such statistical anomalies derive from an ability of the human operator to observe and collapse the quantum-mechanical wavefunction by extra-sensory means, rather than from an ability to select from allowed outcomes. First results from York University have already been reported elsewhere, couched in these terms (Jeffers, 1996). Briefly, human operators were invited to “visualize” (observe, by extra-sensory means) monochromatic light passing through a double slit, *prior* to its registration as an interference pattern by an optical detector. It was predicted that such extra-sensory observation would manifest as a measurable departure of the interference pattern from theory due to premature wavefunction collapse.

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Equipment

As sketched in Figure 1, a double-slit interference pattern is generated by a low power He-Ne laser illuminating a commercially available stainless steel disc in which two slits are cut $10\ \mu\text{m}$ wide and $10\ \mu\text{m}$ apart. The resulting interference fringes are detected by a linear diode array (Princeton Applied Research Model #1453 with 1024 diodes). Figure 2 shows an ideal (scalar Fraunhofer theory) interference pattern to which the measured interference pattern has been shown to conform very closely after subtraction of background counts and correction for gain variation of the detector array (Jeffers *et al.*, 1992). A stepper motor is used to chop the beam close to the laser aperture, effectively blocking the beam for two out of every three seconds. The diode array responses during the blocked and un-blocked phases are digitized and passed to a PC for analysis. The response during the interval

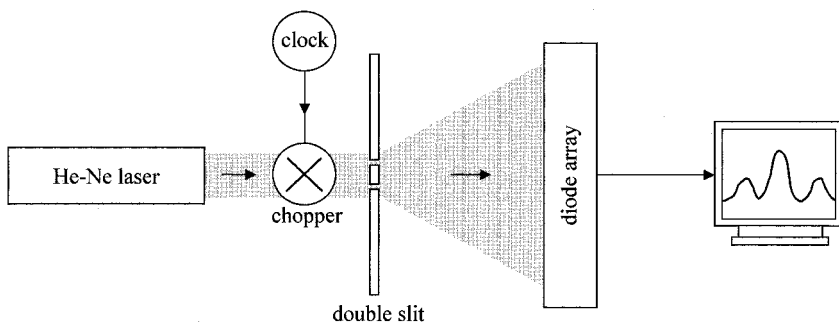


Fig. 1. Schematic of apparatus.

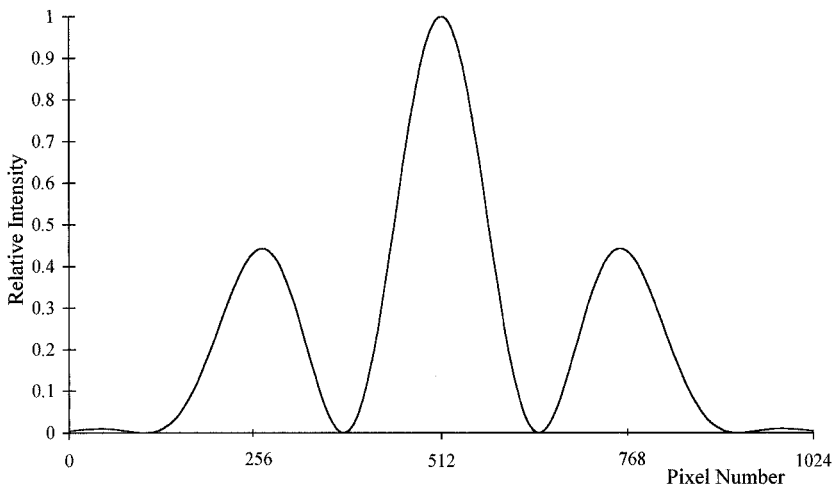


Fig. 2. Double-slit diffraction pattern.

with the beam blocked serves as the background to be subtracted from the response during the subsequent interval with the beam un-blocked.

Objective

The chosen target of the analysis is the contrast of the interference pattern defined as

$$C \equiv \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}}; \quad 0 \leq C \leq 1$$

where I_{\max} is the intensity at the central antinode and I_{\min} is the average of the (two) intensities at the first node on each side of the maximum. To counteract the effects of jitter in the interference pattern, the locations of the extrema are determined afresh for each exposure. The values of the intensity extrema are deduced from the stationary points of a quadratic fit to the intensities (*i.e.*, diode responses) at the three detector positions spanning each extremum.

Protocol

Each one-second (un-blocked, background subtracted) exposure — called a *trial* — provides the sample values for the contrast. An operator session at the machine consists of a *series* of 41 *runs*, alternately designated active or inactive, comprised respectively of 11 and 10 trials each (Figure 3). During the active runs, the interference pattern and an analogue indicator indicating the contrast (a vertical bar of variable height) are displayed to the operator and updated immediately following the close of each trial. During the inactive runs the display is blanked and the operator remains present but does not try to influence the results. (In use, operators found the analogue indicator a more useful form of feedback than the plot of the interference pattern).

Prior to participation in the experiment, the operators at York were advised to imagine that during the active runs they could identify (by extra-sensory means) the path of the light beam near to the double slit. They were told that success at this task would be reflected in a less-well-defined interference pattern, and a corresponding reduction in the contrast reported by the analogue

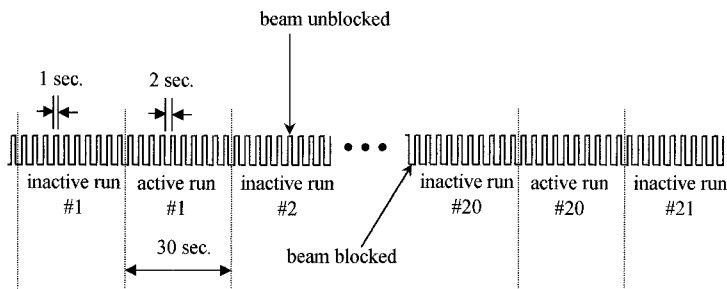


Fig. 3. Division of an operator session (series) into runs and trials.

indicator. There was no prior decision to run the experiment for a particular number of series.

The operators at Princeton were given a slightly more goal-directed task. Though it was explained that the experiment was designed to measure anomalous wave-function collapse, operators were told that their primary task was to intend the analogue indicator bar to remain as low as possible. Due to already heavy demands on operator time, a prior decision was made at Princeton to run the experiment for just 20 series, and then to analyze the data and report the results.

Controls

At York, calibration runs consisted of 350 repetitive measures each comprising one second duration. At Princeton, calibrations were run in the same manner as the experiment, but with no operator present. Calibration data were gathered for approximately 100 series both before and after the 20 series comprising the main experiment. To protect against thermal effects, the apparatus was otherwise continuously on, even though not collecting data, and no experiments were performed for 24 hours after a power failure. The control data from both sites were found to conform to chance expectation.

Results

Figures 4 and 5 show chronologically the active series results from York and Princeton, respectively. The Z-score (Hays, 1994) for each series is computed from the difference in contrast between the active and adjacent inactive runs. The variance used is the empirical variance of the contrast during the adjacent inactive runs.

The results from York have been reported previously as a table of contrast

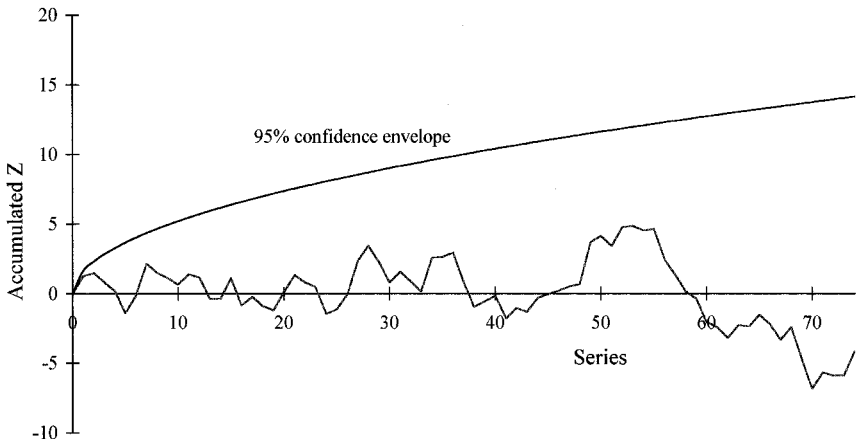


Fig. 4. Contrast Z-score for data from York University.

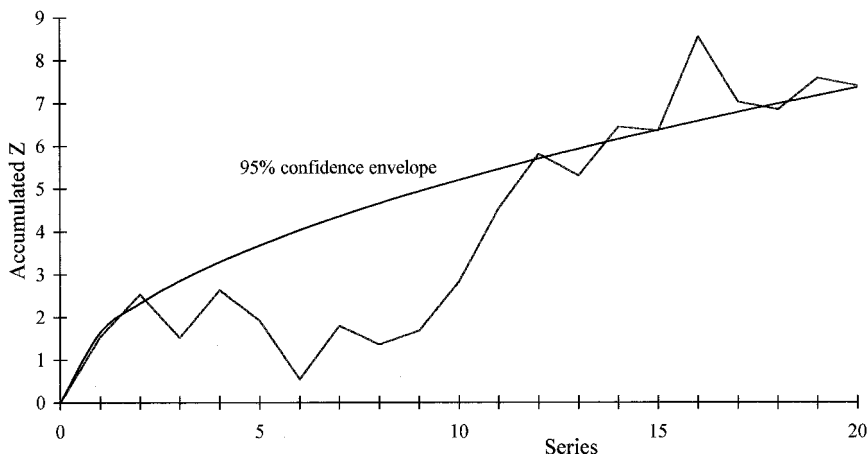


Fig. 5. Contrast Z-score for data from Princeton University.

and variances (Jeffers, 1996). Note however that the column headings therein were incorrectly labeled: the active and inactive data were transposed. The reported conclusion, that there was no effect of operator intention on the contrast, was based upon analysis of the inactive data. Nonetheless, the conclusion here is the same; the correctly labeled results also show no statistically significant effect of operator intention ($Z = -0.481$).

In contrast, the results from the Princeton experiment are just significantly different from chance at the 5% level, with a terminal Z of 1.654. Despite the marginal nature of the statistical yield, the scale of the observed effects is consistent with that observed in other Princeton experiments where substantially larger databases produced significant departures from chance (Jahn *et al.*, 1997).

In a secondary analysis the York results showed some other curious, if not anomalous, statistics. Of the 74 series, 14 show $|Z| > 1.645$, whereas the expected count is 7.4 ($p = 0.014$) which is largely attributable to an excess of negative results ($Z < -1.645$; 3.7 expected, 9 observed, $p = 0.011$). As a consequence of this finding, we looked at the variances of the series Z -scores, and found that they were indeed significantly elevated ($\equiv 1.185$; $\chi^2 = 102.4$, 73 DF , $p = 0.013$). The source of the variance increase is not known, but the same tests reveal no such anomaly in the control data.

Discussion and Further Work

Given the ample evidence in the literature of statistical anomalies correlated with human intention, the major motivation for this effort was to improve our understanding of the dependencies and invariants of the process, rather than simply to provide more evidence of such anomalies. From this perspective we

note that this particular anomaly apparently depends on some physical or psychological parameter which takes on different values in the experiments at York and Princeton. One possible candidate is the instructions to the operator; *i.e.*, goal-directedness versus “means-directedness” at Princeton and York respectively. Possibly more relevant is the wider difference in approach and philosophy of which these are consequences. There has evolved at Princeton a laboratory culture and approach which seeks to ease the interface between operator and machine, primarily through laboratory ambience, experimental setting, and the informal relationship between operators and laboratory staff within which efforts are made not to regard the former as subjects of study. The operators are uncompensated and encouraged “to have fun” with the experiment. However, given the vast number of other psychological and physical factors that conceivably could be relevant, proper discrimination will require further experimentation. Clearly, larger databases from both laboratories would be desirable to consolidate these pilot findings.

Subsequent reconsideration of the conceptual foundation of this experiment led to the conclusion that, without supplementary constraints, premature wavefunction collapse is indistinguishable from the action of an anomalous force; anomalous wavefunction collapse prior to conventional sensory observation can be equally well described by the insertion of an anomalous potential into the Hamiltonian, adaptively tailored to bring about the desired correlation of final observation with intention. The class of model that seeks to explain statistical anomalies in these terms may be designated “physically-motivated” (*e.g.* Forwald, 1969), in contrast with “statistically-motivated” models, which includes Decision Augmentation Theory (May *et al.*, 1995) and other statistical influence models.

In the spirit of the original conception of this experiment, a critical test to discriminate between physically-motivated and statistically-motivated models would involve measurement of a quantity not subject to statistical fluctuations. If the unperturbed probability for the value of some observation is $p(x)$, statistically-motivated models require a non-zero $p(x)$ to produce an anomaly; physically-motivated models do not. Unfortunately however, the chosen focus for this experiment — the fringe contrast of the interference pattern — is intrinsically noisy (around 5% of the peak value). Further, it was discovered that the contrast noise was not due to the “granularity” of light at low photon fluxes, but originated from within the detector itself; presumably the thermally generated dark noise super-imposed on the detected signal. Hence, it was concluded that the experimental measure functioned essentially as a noise process, fundamentally no different from the random event generators ubiquitous to this field, and therefore was inadequate to distinguish between these two classes of model.

A discriminating test in a revised version of this experiment is possible if the intensity at a noise-free node in the interference pattern is the target of intention. Since $p(x)$ would then by definition be zero, anomalous appearance

of a non-zero intensity at the erstwhile nodes could not be accommodated within a statistically-motivated model. An anomalous force (effectively: the appearance of an anomalous refractive index in the path of the beam), or perhaps premature wavefunction collapse, would then be the preferred candidates. Possible future experiments along these lines are under consideration. B. Haisch (private communication) has made a suggestion for a yet more discriminating test: see if anomalous perturbation of the interference pattern can be adequately explained by contributions from two super-imposed single-slit interference patterns. (Note however that correspondingly more data would be required to resolve a particular induced pattern in the noise than just to determine the deviation from expectation).

Summary

A Young's double slit interference experiment has been conducted which tested the capacity of human operators to change the interference pattern in accord with their intention. The experiments conducted at York University did not show any evidence that the human operators tested can succeed in this task. The experiments conducted at Princeton University showed marginal evidence of an anomalous effect at a scale consistent with that of similar experiments with larger databases and corresponding larger effects.

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