Reassessment of an independent verification of psychophysical interactions with a double-slit interference pattern

Dean Radin,[1,a)] Leena Michel,[1] and Arnaud Delorme[2]
[1]*Institute of Noetic Sciences, 625 Second Street, Suite 200, Petaluma, California 94952, USA*
[2]*University of California, San Diego, 9500 Gilman Drive, La Jolla, California 92093-0559, USA*

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Abstract: In an independent analysis of data from a double-slit experiment designed to investigate von Neumann-like psychophysical interactions, Baer [Phys. Essays **28**, 47 (2015)] concluded that shifts in interference pattern minima showed a small but consistent effect in alignment with what we had previously reported. But because the standard deviation of those measurements was large compared with the mean, Baer concluded that the optical system was not sufficiently sensitive to provide convincing evidence of a psychophysical effect. However, this type of assessment should rely on standard error, not standard deviation. When the proper statistic is employed, Baer's calculations show a modest but statistically significant deviation of the central minima in data contributed by human observers ($p = 0.05$, one-tail), but not in sessions contributed by robot "observers" ($p = 0.26$, one-tail). In addition, when considering the central minimum along with eight other minima, the human-observed grand mean was significantly larger than the robot-observed grand mean ($p = 0.008$). Thus, Baer's independent analysis confirmed that the optical apparatus used in this experiment was indeed sensitive enough to provide evidence for a psychophysical effect. © *2015 Physics Essays Publication*. [http://dx.doi.org/10.4006/0836-1398-28.4.415]

Résumé: Wolfgang Baer [Phys. Essays **28**, 47 (2015)] a mené une analyse indépendante de données provenant d'une expérience double fente que nous avons réalisée. Cette expérience était conçue pour étudier les interactions psychophysiques avec des effets de type von Neumann. Wolfgang Baer conclu que les changements dans les franges d'interférence montre un léger mais constant effet en accord avec ce que nous avions montré précédemment. Toutefois, du fait que l'écart type des minima d'interférence était élevé par rapport à la moyenne, Baer conclu que notre système optique n'était pas suffisamment sensible pour fournir des preuves convaincantes d'un effet psychophysique. Cependant, ce type d'évaluation devrait utiliser l'erreur standard et non l'écart-type. Lorsque les statistiques appropriées sont utilisées, les calculs de Baer montrent un écart modeste mais statistiquement significatif du minimum central d'interférence dans les données produites par les observateurs humains ($p = 0{,}05$; test unilatéral), écart qui n'est pas présent dans les données produites par les observateurs robots non humain ($p = 0{,}26$; test unilatéral). En outre, lorsque l'on considère les huit autres minima d'interférence en plus du minimum central, la grande moyenne observé pour les sujets humains était significativement plus grande que la moyenne générale observée pour les robots ($p = 0{,}008$). Ainsi, une analyse indépendante de Baer confirme que l'appareil optique utilisé dans cette expérience était en effet assez sensible pour fournir la preuve d'un effet psychophysique.

Key words: Quantum Measurement Problem; Consciousness; Double-Slit Experiment; von Neumann.

I. INTRODUCTION

In a series of experiments using optical interferometers, we investigated the postulate that consciousness is involved in the collapse of the quantum wavefunction through what John von Neumann called a "psychophysical" interaction.[1–3] Data collected in our experiments appear to be consistent with the notion of such an interaction, although it is not certain that consciousness *per se* was the only possible cause for the results we observed.

After reading our reports, Baer requested a copy of data from an online version of one of these studies.[3] His goal was to apply a simpler form of analysis than the method we used, which had been designed to accommodate the mode-hopping behavior of the HeNe laser used in the optical system. Our method included various preprocessing steps requiring a Fourier Transform, detrending, smoothing, log transforms, and so on. Baer found no flaws in our method, but he felt that a simpler analysis might be more persuasive. We agreed

[a)]Author to whom correspondence should be addressed; electronic mail: dean@noetic.org

that a fully independent analysis would be valuable, so we gave him with a copy of the data.

II. DISCUSSION

Baer's primary result, shown in Table 1 of his article, was a summary of his analysis based on some 1435 test sessions contributed by humans and 2230 sessions contributed by a computer programmed to simulate humans (called "robot" sessions).[4] The most sensitive portion of the interference pattern is the central minimum, which Baer called the "first minima." If von Neumann's postulate was correct, then when attention was focused on the double-slit system the first minima should increase, as compared with when attention was withdrawn, because the wavelike interference that sustained the minimum would decline, thereby allowing more photons to arrive at that location. The mean of this value reported by Baer for the human sessions was 0.00281 with a standard deviation of 0.0639; for robot sessions it was 0.000812 with a standard deviation of 0.0588. From this he concluded that the noise level, as reflected by the standard deviations, was too high to provide evidence for a psychophysical interaction.

We appreciate Baer's simpler analytical approach, but his assessment should have relied on standard error rather than standard deviation. Standard deviation is a measure that is used to quantify the amount of variation or dispersion in a sample. It should not be used in inferential statistics. That is, to statistically compare an observed mean against a hypothesized population mean (which in this case equals zero, meaning no difference in fringe minimum during the concentrate versus relax periods), we need to estimate the error in our observed standard deviation. That value is known as the standard error, which is proportional to the square root of the underlying sample size. Thus, using the standard equation for a one sample t-test, (Ref. 5, p. 95) $t = (\bar{x} - \mu)/se$, where $se = s/\sqrt{n}$, $\bar{x}$ is Baer's calculated value for the observed sample mean, $\mu = 0$ for the hypothesized population mean, s is Baer's calculated standard deviation, and n is the sample size, we find that the first minima for data contributed by humans results in $t = 1.67$. In this case, given large n, the t score is essentially equivalent to what in physics is more commonly known as sigma, and thus if an effect is 1.67 sigma from a null effect, it is associated with a probability of $p = 0.05$ (one-tail, given the null hypothesis is directional). The same analysis applied to sessions contributed by robots results in $t = 0.65$, or 0.65 sigma, a statistically nonsignificant effect associated with $p = 0.26$ (one-tail). In addition, when considering the nine minima listed in Baer's Table 1 for both human and robot sessions (i.e., the central plus eight adjacent minima), the mean difference compared by a paired t-test is associated with $p = 0.008$ (one-tail). In other words, using standard deviation instead of standard error can make a large difference, indeed a factor of $\sqrt{n}$, but of greater importance it is the proper measure when making statistical inferences, as in the present context.

We may note that a t-test assumes that all samples are independent, which is not the case for interference minima, and thus an adjusted p-value associated with the latter test would probably be somewhat larger than $p = 0.008$. Nevertheless, this outcome suggests that numerous minima shifted in the same direction, which is consistent with the idea that a psychophysical effect would systematically influence the entire interference pattern.

It is also worth mentioning that while an analysis based on shifts of interference minima is simpler than the approach we originally used, it does not take into account the unavoidable mode-hopping behavior inherent to HeNe lasers. Mode hopping increases the variance of measurements of the minima, thus reducing statistical sensitivity when comparing means between two conditions. To overcome this problem, in our more recent studies we have been using fringe visibility as the measurement of interest.[6] This is conceptually as simple as interference minima, but as a *relative* measure it takes into account power variations introduced by mode hopping, and statistical comparisons between the two attention conditions are straightforward.

III. CONCLUSION

Using an independently developed analytical approach, Baer found a modestly significant von Neumann-like psychophysical interaction effect in data generated by our optical double-slit system, confirming our previously reported result.

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