Original Article

A Game-Theoretic Approach to Metaphysical Reconciliation of Quantum Superposition

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Abstract
The well-known quantum physical paradox of wave-particle duality principally arises from the physicists' definition of the phenomenon of *quantum superposition*. In this paper, we look at the possible philosophical rather than physical implications of this phenomenon and posit an independent metaphysical reconciliation based on game theory

Key Words: quantum metaphysics, wave-particle duality, quantum superposition, collapse of the wave-function, zero-sum games

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The two-slit *gedankenexperiment* revisited

The classical experimental set-up consists of a screen with two slits s_1 and s_2, which can be opened and shut as required. A beam of electrons is fired at the screen from an electron gun. Behind the screen there is some kind of an electron detector like a metallic plate smeared with photographic chemicals.

Experiment conducted *without* observer participation

When slit s_1 is opened and slit s_2 is shut, the fired electrons are detected on the photographic plate in a cluster just behind s_1. A similar cluster is observed to form just behind s_2 if s_1 is closed and s_2 is opened instead. However, if both slits s_1 and s_2 are opened together, an interference pattern is observed strongly implying a wave-like nature of the electron beam.

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Experiment conducted *with* observer participation

Keeping both slits open, if any conscious effort is made to detect the electrons at the precise point when they pass through one or the other slit, the interference pattern strangely disappears and the electrons strongly exhibit a particulate nature! It is as if Mother Nature behaves in one way when we are looking and in a completely different way when we are not! Such *dualistic* behavior is a fundamental characteristic of all sub-atomic particles.

A simple physical interpretation of the wave-particle duality

The electrons, left to themselves, behave as a wave. However, any attempt to observe the electrons at the point where they pass through either one or the other slit calls for the use of light or some other electro-magnetic wave. However, light wave is in turn made up of 'packets' of photons with a shorter wavelength than the electron beam and this 'disturbs' the experimental set-up causing the electrons to behave as particles rather than a wave.

Keeping both slits open, if any conscious effort is made to detect the electrons at the precise point when they pass through one or the other slit, the interference pattern strangely disappears and the electrons strongly exhibit a particulate nature!

Why a physical interpretation cannot resolve the problem in metaphysical terms

The fact that an electron behaves as a particle when directly observed and as a wave otherwise, necessarily implies that they *inherently possess* the characteristics of both a particle *and* a wave at the same time (Dirac, 1958). But the interference pattern observed on the photographic plate is due to the electron beam passing through both the open slits at the same time, which is clearly not possible if we ascribe a classical particulate nature to the stream of electrons, akin to a stream of lead pellets.

However physicists argue that sub-atomic particles do not behave as classical particles under certain circumstances where they may exist in ghostly, *entangled* states (Messiah, 1985). This phenomenon is termed by physicists as *quantum superposition*; and strains the definition of objective reality as we know it. However superposition of waves is not a puzzling phenomenon at all as it may be easily explained in terms of classical physics as simply the result of taking suitable combinations of the field strengths.

So the wave interpretation is not an explanation of the inherent cause of the wave-particle duality, it is merely a convenient mechanism to explain the resulting effect. (Rae Alastair, 1986) The problem becomes even more compounded when we try to measure it up in metaphysical rather than starkly physical terms. This is primarily because of a *lack of philosophical interpretation* till date of the so-called quantum superposition.

Re-casting the problem in terms of statistical logic

For our purposes, let a "success" be defined as the joint event $X = \{S_1 \cap D\}$ i.e. the detected electron passed through slit s_1 (Forrest, 1988). (Of course X could very well be $\{S_2 \cap D\}$ without affecting any of our analysis). Thus, in terms of classical probability theory, we record a "success" (denoted by 1) when an electron is detected on the photographic plate and it has passed through slit s_1; and a "failure" (denoted by 0) when an electron is detected on the photographic plate and it has passed through slit s_2.

Wave interpretation is not an explanation of the inherent cause of the wave-particle duality, it is merely a convenient mechanism to explain the resulting effect

When the system is in a *superposed state* prior to a direct observation near the slits, "failure" and "success" as defined are not discrete, disjoint events but rather *span a continuous interval* in the range (0, 1). Therefore, the expected value of X will be given formally as follows:

$$E(X) = \int_0^1 X\, P(X)\, dX, \text{ where X is a continuous random variable in the interval } (0, 1)$$

The physical explanation of all this is that an electron may *both pass and not pass* through s_1, which is by itself a long-standing metaphysical paradox begging some kind of a philosophical interpretation (Gibbins, 1987).

Once however an attempt is made to directly observe the electron at the precise point where it passes through one or the other slit (or both), there is an instantaneous *collapse* of the superposed state to the classical, particulate state, a metamorphosis, which we hereby christen as a *λ-transformation*. Following the λ-transformation "success" and "failure" as defined once again become disjoint, mutually exclusive events that may now be appropriately characterized by a *discrete Bernoulli distribution*. That means we now have only two mutually exclusive possible outcomes – either a "success" or a "failure", rather than the earlier case of a metaphysically unwieldy "success – and – failure". The expected value of X is then obtained as follows:

$$E(X) = \Sigma_i\, X_i\, P(X_i) = \Sigma_i\, [X_i\, \lambda^{Xi}\, (1-\lambda)^{(1-Xi)}] = \lambda$$

Of course, in a physical sense, the λ-transformation then is the collapse of the wave-function. But the question we pose (and also attempt to answer) is that whether can there be a *purely philosophical* (as opposed to the *starkly physical*) interpretation of the phenomenon that we have referred to here as the λ-transformation (Honner, 1987).

The game Mother Nature could be playing: a game-theoretic approach to the metaphysical reconciliation of quantum superposition

Under the game theoretic approach to the problem of wave-particle duality our basic philosophical premise is that when Mother Nature is faced with an *either-or* situation, the Universal neutrality with respect to the chain causality is temporarily suspended. This is analogous to Mother Nature virtually "splitting" into two mutually competitive entities; which by philosophical extension may be termed *God* and *Devil*. It must however be borne in mind that such a nomenclature has *no* theological significance but is only employed to mark the mutually competitive nature of these virtual entities.

Let us, for a start, view the electrons as a stream of particles in accordance with the *old quantum theory* that originated from Max Planck's studies on *black-body radiation* (Sakurai, 1985). We define the following elementary events:

N = {E | E is an electron which is fired from the electron gun}

D = {E | E is an electron which is detected on the photographic plate}

D' = {E | E is an electron which is *not* detected on the photographic plate}

S_1 = {E | E is an electron which has passed through s_1}

S_2 = {E | E is an electron which has passed through s_2}

Applying the classical theory of probability we derive the following equations:

$P(S_1 \cap D) = P(D) \times P(S_1 \mid D) = [n(D)/n(N)] \times [n(S_1)/n(D)] = n(S_1)/n(N) = \lambda$ … (i)

$P(S_2 \cap D) = P(D) \times P(S_2 \mid D) = [n(D)/n(N)] \times [n(S_2)/n(D)] = n(S_2)/n(N) = \lambda'$ … (ii)

Now, keeping $P(D) = n(D)/n(N)$ constant, λ can increase only if λ' decreases by the same magnitude. This forms the fundamental premise of a *two-person zero-sum game* having the following pay-off matrix with respect to the player *God*:

"God"		"Devil"	
		S_1	S_2
	S_1	λ	$(\lambda - \lambda')$
	S_2	$(0 - 0)$	$(0 - \lambda')$

Now, as $\lambda \geq 0$, we therefore have $(\lambda - \lambda') \geq (0 - \lambda')$. Similarly, as $\lambda' \geq 0$, we therefore have $\lambda \geq (\lambda - \lambda')$. Therefore, the above pay-off matrix has a *saddle-point* at cell S_1S_2 and the value of the game is $(\lambda - \lambda')$ (Freund, 1992).

Note that the expected value of $\{S_1|D\}$ as given by the discrete Bernoulli distribution is λ. However, since $\lambda \neq (\lambda - \lambda')$ for $\lambda' \neq 0$ and $\lambda' \neq (\lambda - \lambda')$ for $\lambda' \neq \lambda/2$, the value of the game can neither be λ nor λ', but *somewhere in between* – the fall-out of which, in physical terms, can be interpreted as the quantum superposition!

Therefore, the critical values of λ' are $(0, \lambda/2)$. The collapse of the wave-function, in our metaphysical model, then merely becomes a *special case* where λ' attains either one of these two critical values! When $\lambda' = 0$ or $\lambda' = \lambda/2$, Mother Nature once again becomes neutral with respect to the chain of causality i.e. the competitive entities merge back together thereby removing all the physical manifestations of *dualism* (Brown and Harre', 1988). This, in effect, can be the metaphysical interpretation of our λ-transformation!

As a concluding remark we would like to emphasize the fact that what we have developed here above is not any new, empirically testable explanation of quantum phenomena but rather an attempted metaphysical reconciliation of quantum superposition using an unconventional methodological approach.

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