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Quantum Indeterminacy and Libertarian Panpsychism

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Abstract

The “consequence argument”, together with the “luck objection”, which are summed up by the “standard argument against free will”, state that if our volition were dependent on physical causally indeterministic processes, our actions would lack control and, thereby, result in random behavior that would be a mere matter of luck and chance. In particular, quantum indeterminacy is supposed to be of no use in support of libertarian agent-causation theories because any volitional act interfering with the probability distributions defining quantum laws would lead to its violation. Building upon recent conjectural work questioning this assumption (Clarke 2010, Kastner 2016, Masi 2023), it is shown, with a concrete example involving quantum indeterminacy, how a hypothetical agent with access to the temporal ordering of events can pre-determine the result of a process taking place in time without modifying the probability laws defining it. This conclusion is then taken as a basis for a libertarian panpsychist interpretative model.

1. Introduction

The question of whether a relationship exists between free will and quantum mechanics is longstanding. One of its motivations is to present an alternative to compatibilist accounts which see determinism as reconcilable with free will, while an incompatibilist or libertarian view rejects such compatibility. Compatibilists and libertarians both believe in free will, but they diverge on whether physical causal determinism is compatible with notions of free agency, or whether (classical or quantum) indeterministic processes are necessary as a “reservoir” allowing an agent to make free choices unconstrained from other external factors. The latter incompatibilist position differentiates event-causation from agent-causation libertarianism.

Event-causation libertarians posit that actions are caused solely by events. Actions are conceived of as agent-involving events caused solely by prior events, and an agent’s freedom of choice is reducible to events causally involving him in making the choice. However, if so, such libertarianism is arguably inconsistent because the extent of the agents influence on his decision is limited to the causal impact of states and events directly involving him.

Meanwhile, agent-causation libertarians do not start from an event causing another event but, rather, from a "being" who can settle the matter of which options for action should occur. Agent-causation suggests that an agent has a unique causal power to choose without being causally predetermined to do so. However, the issue with agent-causation is that any undetermined agent-caused action seems to imply physical changes that would lead to divergences from the known physical laws (Pereboom 2001, p. 81; 2014, pp. 65–69).

The present paper aims to demonstrate, with a specific example from quantum physics, how libertarian agent-causation that doesn't imply violations of physical laws is naturally recovered if we do not abstract from the temporal dimension of the processes ruled by probabilistic laws and how it lends itself to a panpsychist metaphysical framework. However, before getting there, it might be instructive to briefly review the main objections that stand in the way of this worldview.

The canonical version of the incompatibilist argument is the "consequence argument" presented by van Inwagen (1983, p. 3) as follows:

> If determinism is true, then our acts are the consequence of laws of Nature and events in the remote past. But it's not up to us what went on before we were born, and neither is it up to us what the laws of Nature are. Therefore, the consequences of these things (including our present acts) are not up to us.

On the other hand, the challenge to libertarianism is the "luck objection", according to which there cannot be any exercise of free will based on causally undetermined actions, as these would be based on mere luck or chance, for which no one is morally responsible (Shabo 2020).

I would like to present this issue in a more physical context of microphysical causation. To this purpose, the so-called "standard argument against free will" neatly summarizes the two perspectives. Roughly speaking, it goes as follows (for an in-depth analysis see Doyle 2011). The libertarian challenges the compatibilist with the "determinism objection": If the universe is ruled by a physical causal determinism, all its dynamics, from the micro- to the macro-cosmos, are ruled by a strict physical bottom-up causality. Then no room is left for free agency, not even in principle. This is because if everything is determined from the atomic scale upwards to the brain, then all our actions must be determined as well. Therefore, if we have free will, it must be rooted in non-deterministic processes such as those physics describes at a quantum level.

This latter hypothesis, however, isn't unproblematic either and is challenged by the "randomness objection": If our brain states are ultimately dependent on some random processes, then our thoughts, desires, and will to act would result in a random and uncontrolled series of behaviors. Random events are no more within our control than deterministic ones. Thus, either way, there is no freedom of action, neither in determinism nor in indeterminism. Free self-determination seems to be incompatible with modern physics.

There have been different attempts to overcome one or the other objection (for an overview, see Kane 2012b). However, they mostly rely on notions of "indeterminism" that are rooted in pseudo-random processes. Also, in a deterministic universe dominated by the physical causal determinism of classical physics, the "indeterministic noise" that the agent "harnesses" on a macroscopic higher-level, isn't ultimately indeterministic; rather, it is grounded in a lower-level micro-physical determinism and, thereby, remains inside a deterministic paradigm. The switch from a classical to a quantum indeterministic ontology is, in my view, an unavoidable step one must still take. A causal classical physical deterministic low-level ontology, even if based on pseudo-random events, on the unpredictability of a non-linear complex system and deterministic chaos, or whatever kinds of classical stochastic processes, does not become consistent with any higher-level free-will theoretical framework. Especially from the event-causation libertarian perspective, the agent's causal power over this stochasticity remains unclear. Therefore, here, I would like to investigate further the possible logical relationship between quantum indeterminacy and agent-causation.

Yet, there are conceptual hurdles to overcome. Already, giants of science such as Schrödinger (1951, pp. 162ff) commented on this, asking: "Would physical indeterminacy give free will a chance?" He concluded that it is an impossible solution because "the direct stepping in of free will to fill the gap of quantum indeterminacy does amount to an interference with the laws of Nature".

While Searle (1986, pp. 86f) once stated that

> even if there is an element of indeterminacy in the behavior of physical particles – even if they are only statistically predictable – still, that by itself gives no scope for human freedom of the will; because it doesn't follow from the fact that particles are only statistically determined that the human mind can force the statistically determined particles to swerve from their paths. Indeterminism is no evidence that there is or could be some mental energy of human freedom that can move molecules in directions that they were not otherwise going to move. So it really does look as if everything we know about physics forces us to some form of denial of human freedom.

This view is reiterated by other prominent scientists and philosophers and remains, to date, a widely accepted opinion, and that Müller called the "statistics objection": Any interference by a willful agent with (classical or quantum) indeterministic events would inevitably lead to the violation of the statistical laws. Such an interference would lead to the modification of the profile of the probability distribution (PD) describing it. Thereby, this would render any libertarian view of free will based on principles of indeterminism in conflict with the laws of physics. In other words, we must conclude that we are "slaves to the probabilities".

Clark, however, realized that things aren't as simple as that, pointing out that an agent, even if subjected to strict probabilistic laws, is, nevertheless, not instructed to follow any particular sequence to produce a predetermined distribution, as "probabilistic laws of Nature also do not require, for any finite number of trials, a precise distribution of outcomes" (Clarke 2010, p. 390). We are free to choose the order in which things happen provided that they approximate a prescribed PD in the limit of large numbers. Kastner further showed that the violation by agent-causation of the Born rule, which is the formal basis for every PD for measurement outcomes in quantum mechanics, can't be taken as a litmus test for or against free will. Choices of complex macro-creatures are not accurately modeled by unique quantum observables on quantum states and, thereby, can't be tested by Born probabilities (Kastner 2016). Masi reviewed these aspects by adding some thoughts, clarifying first the distinction in physics between classical and quantum indeterminism and reviewing the old metaphysical idea of self-causation (*causa sui*) (Masi 2023).

Here I will complement the above insights, especially expanding on Clark's claim. While it is true that we are not forced to obey probabilistic laws following any particular predetermined series of outcomes, it isn't entirely clear how much freedom of choice this leaves. To investigate this aspect, the present work has been inspired by an original idea of British analytic philosopher Elizabeth Anscombe who wondered about this in the form of a classical thought experiment, nowadays known as the "Anscombe box" (Anscombe 1971, for a review of the Anscombean perspective see also Mulder *et al.* 2022). She imagined a box filled with colored particles whose dynamics are ruled by statistical laws. Suppose it displays on its sides a particular pattern with slightly varying shapes and sizes but, nevertheless, has certain recognizable regularities. Her thesis was that "it is not at all clear that those statistical laws [...] would have to be supposed violated by the operation of a cause for this phenomenon" (Anscombe 1971, p. 146, as cited by Mulder *et al.* 2022).

Anscombe did not further develop her thoughts on this. Recently, however, Müller made a computer simulation of such a box and showed that, indeed, it is possible to intervene in the dynamics by flipping the position or colors of some particles making appear repeatedly similar pattern without changing the statistics of the process (Müller 2022). As Mulder *et al.* (2022, p. 9) summed it up:

> agency might be a higher-level, emergent power that realizes possibilities left open by the lower level laws that govern, say, agents' bodies.

Anscombe was more concerned with defining the principle of causality and its relation to determinism rather than applying it to philosophical questions regarding free will. Van Miltenburg further worked on her legacy, discussing an alternative to determinism in terms of probabilistic causation and different kinds of causality (van Miltenburg 2022), and Mulder pointed out how life as such requires physical indeterminism (Mulder 2021). While the present approach could be useful in clarifying aspects of the randomness objection. I present a similar but more general argument and simulation that aim at a deeper understanding of the relationship between indeterminacy and agency.

The present work is subdivided as follows. Section 2 provides a more general and formal description, which elucidates how there is virtually an infinite number of possible ways to approximate a probability law without modifying its representation, that is, leaving it invariant. This aspect frequently remains unnoticed because we tend to think of probability functions independently of their temporal dimension. Section 3 seeks to clarify this further with the specific example of Young's famous double-slit experiment. With a simple computer simulation, it is possible to show how an agent can choose the appropriate sequence of outcomes subjected to a probability law inducing a random walk of a particle, which, nevertheless, can be directed towards a chosen target without violating the laws determining its random dynamics. Section 4 will provide a brief tentative suggestion of how the obtained results could be implemented inside a libertarian panpsychist framework. If quantum mechanics could, at least in principle, open a door to micro-physical agent-causation, this could naturally lend itself not only to some form of micropsychism but also to a cosmopsychist metaphysical paradigm. Concluding remarks then follow.

2. Randomness, Probability Distributions, and Time: A Brief Formal Reminder

Despite their pervasive use in our common language, the words "randomness" and "indeterminacy" have no unique, rigorous, and universally accepted definition. Perhaps the most widely accepted version of randomness is that which is based on the works of Chaitin's algorithmic information theory and which links what he called Kolmogorov randomness to the notion of complexity: Random is everything that is represented by an incompressible string and, thereby, that has maximum complexity

(Chaitin 1975a,b). However, this definition is of little practical use because it is limited by Gödel's theorem of incompleteness, which forbids even in principle the knowing of whether a program's length is the shortest that describes the data in the first place. Therefore, let's take a simpler but still widely accepted understanding.

In our common understanding, a process is random when all its possible outcomes have equal probability of being realized, that is, what is called white noise. This, however, is a much too restrictive definition. In fact, in statistical mathematics, one speaks of random variables linking it to a PD. It is of more practical use to label a process as having a degree of randomness or indeterminacy when its outcomes are not predictable with certainty, but that can, nevertheless, be described statistically by a PD (or continuous probability density functions).[1]

Let us then consider a discrete random variable $X : \Omega \to \mathbb{R}$ – that is, a measurable function X from a countable sample space Ω (i.e., a finite or countable infinite number of distinct values) to the real numbers $\mathbb{R}$ of the set of possible outcomes. Let $P(X)$ be its discrete PD[2] defined as the set of nonzero probabilities that the discrete random variable X assigns to a countable number of distinct values $x_i (i = 1, ..., c)$ as [3]

$$P(X = x_i) = p_i = \frac{n_i}{N} \tag{1}$$

with $X = x_i$ a particular realization of X, n_i the number of favorable outcomes for the i^{th} possible outcome, N the total number of events or measurements, and c the number of all possible outcomes, such that, in the limit of large numbers $N \to \infty$, for a normalized PD, $\sum_i p_i = 1$.

Typical examples are the two possible outcomes of a coin toss, or, in quantum mechanics,[4] the measurements of the spin of a particle ($p_i = 1/2, i = 1, 2$), or a dice toss ($p_i = 1/6, i = 1, ..., 6$), etc. A more general case of a discrete PD is the Poisson distribution, which expresses the probability of observing a certain number of occurrences once the expected

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[1] Notice how even this is not completely unproblematic because, for example, a sequence of equally probable binary digits of length N, such as 10101010101010101010..., could hardly be called random, with its two digits appearing with equal relative frequency. However, this sequence can still be called random, provided that, on average, it doesn't appear more than once over 2^N times. With a general PD, things would be formally more complicated but the underlying principle does not change. These kinds of issues inspired Kolmogorov and Chaitin to search for a rigorous definition of randomness. However, these formal aspects are not of concern here as long as this provision is observed.

[2] Here discrete PDs are assumed, if not stated otherwise.

[3] A probability space with well-defined variables need not necessarily appeal to a frequentist interpretation. But in quantum physics, this is always assumed.

[4] Of course, in quantum mechanics, probabilities are given by the Born rule and complex probability amplitudes, defining self-adjoint operators on a Hilbert space. However, in the present context, we do not need to dwell on these formal aspects beyond ordinary discrete PDs.

mean rate of occurrences is known (e.g., the number of photons emitted by a light source in some time interval). Equally, a PD could represent the discretization of continuous probability density functions. Several examples of this kind exist in classical and quantum statistics (we will see a concrete example in the next section). The normal (Gaussian) symmetric and bell-shaped distribution, for example, could describe the state probability of a particle whose measured values have a variance centered on their mean value. The exponential distribution finds its most eminent application in describing transition probabilities such as the decay rate of atomic nuclei, once their specific mean lifetime of radioactive decay is known. The power-law distribution describes the distribution of energy levels of a quantum system and does not always possess a well-defined variance.

These are just a few examples of distributions that arise in classical and quantum random processes. However, the precise mathematical function and which statistical properties it possesses are, for our purposes, not so essential. This is because the argument we are putting forth here is of a general character that applies to any PD representing the predictability (or uncertainty) of specific events *after* the collection of a certain number of measurements in time has been performed. PDs are, so to speak, the convenient "reduction to a single frozen graphical time snapshot" of the sequence of multiple processes unfolding in time.

In fact, it is frequently left in the background that in a spatio-temporal world, all these events are time series. The number of favorable outcomes n_i in Eq. (1) is a count of the measured events corresponding to the i^{th} possible outcome manifesting at n_i instants in a given time interval T corresponding to the duration of the experiment. For most applications, knowing this time series isn't of much interest. A measurement device accumulates the measurements for each outcome and waits until the end of the experiment, then reads out the n_i values defining the PD, without any need to know when each event has taken place singularly. This is also how all probabilistic laws in quantum mechanics are described: by probability functions describing what to expect from a series of N measurements in an interval of time T, but without any prescription as to the order of the outcomes and its actualizations in time. No physical law is defined by such a temporal order. Nevertheless, for our purposes, taking into account this temporal dimension makes the difference.[5]

Let us investigate this first with a simple example. Consider tossing a coin with its two possible outcomes, namely, heads (H) and tails (T). Suppose you toss the coin 10 times, at subsequent times $t = \{t_1, t_2, ..., t_{10}\}$, and obtain a sequence

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[5] The solution of the time-dependent Schrödinger equation may furnish a time-dependent PD, describing, for example, a transient phenomenon, but nothing in it determines the event-time of the outcomes.

$$S = \{H, H, T, H, T, T, H, T, H, T\}.$$

More precisely, we could write

$$S = \{t_1^H, t_2^H, t_3^T, t_4^H, t_5^T, t_6^T, t_7^H, t_8^T, t_9^H, t_{10}^T\},$$

with $t_j^{i_j}$ meaning that we had outcome $i = H, T$ at time $t_j (j = 1, .., 10)$. Eq. (1) asks for the number of trials (i.e., instants in time) returning heads or tails, $n_H = n_T = 5$ on a total of $N = 10$ trials, obtaining equal probability for both events, $p_H = p_T = 0.5$. However, whatever kind of permutation one applies to sequence S, it will not change the relative frequencies. If the trials had a different order of outcomes, say,

$$S^{'} = \{t_1^T, t_2^H, t_3^T, t_4^H, t_5^H, t_6^T, t_7^T, t_8^H, t_9^H, t_{10}^T\},$$

nothing would change as to the probability law. Notice that this is true for any PD in general. Whatever permutation of the set of outcomes (i.e., their order in time of appearance) leaves the number of heads and tails invariant. Eq. (1) needs only the subsets

$$S_H = \{t_1^H, t_2^H, t_4^H, t_7^H, t_9^H\},$$

and

$$S_T = \{t_3^T, t_5^T, t_6^T, t_8^T, t_{10}^T\}.$$

It is the cardinality of S_H and S_T that determines a PD, not any order. Nevertheless, as we will see, this "freedom to permute" can determine a freedom of agency with a causal power that remains "invisible" to any statistical law of nature rooted in PDs.

Let us now investigate this in a more general setting and formal language. In the real world, the frequency of each outcome and the temporal ordering of which outcome actualizes at which time is determined by its likelihood, defined by Eq. (1). Denote with i_j the i^{th} outcome (measurement "channel" with $i = (1, ..., c)$) at the j^{th} time of measurement as $t_j^{i_j}$. Represent the temporally ordered time series S of all the N measurements in the time interval T as:

$$S = \{t_1^{i_1}, ..., t_N^{i_N}\} \tag{2}$$

This is a set that contains more information about a stochastic process than necessary for a PD because it counts not only the outcomes, but also all the instants at which they occur. A mathematically equivalent representation of S is to order the events, not according to their time of actualization, but rather by the order of the outcomes and the series of instants at which they occurred. We can collect the measurement times for a specific outcome n_i as

$$S_i = \{t_1^i, ..., t_{n_i}^i\}; \quad S = \bigcup_i S_i \qquad (i = 1, ..., c). \tag{3}$$

S_i is an ordered time series, that is, $t_1^i < ... < t_{n_i}^i \leqslant T$, with an average time between events $\bar{t}_i = t_{n_i}^i / n_i$, but the temporal separation between each couple of events is scattered stochastically. This confers the uncertainty of the time of actualization and measurement that makes each event unpredictable.

However, in which order we count those events is irrelevant, as we will always obtain the same PD. Were the events to take place with a permuted temporal ordering such as

$$S_i' = \{t_1'^i, ..., t_{n_i}'^i\}, \tag{4}$$

this wouldn't change the probabilities of occurrence of the different possible outcomes because, for whatever event-time series, their cardinality n_i remains the same:

$$n_i = card(S_i) = card(S_i') \tag{5}$$

and the PD of Eq. (1) remains invariant.

Note that this is an exact invariance, provided condition (5) holds. Thus, if the temporal ordering of the outcomes changes, this doesn't perturb the PD, not even negligibly. It simply doesn't modify it at all and, thereby, doesn't constitute a violation of any physical law defined by a probabilistic law.

3. Interfacing the Double Slit to a Particle Random Walk

Let us illustrate the above reasoning with a concrete example relevant to the quantum context. One such example that helps with intuitive visualization could be the temporal unfolding of the photons' detection at the interference fringes from a double-slit experiment. Young's double-slit experiment can also be described by means of classical electromagnetism and wave interference. However, which photon hits which fringe at what time is a purely quantum stochastic process. It is only in the limit of large numbers (that is, when $N \to \infty$ or, equivalently, $T \to \infty$) that the ordinary wave interference pattern becomes visible on a detection screen. This is a macroscopic manifestation of quantum processes. The preference for quantum indeterminism over classical indeterminism is dictated by the fact that the former is believed to be ruled by ontic probability laws, that is, by causally independent events in which the indeterminacy is not due to the lack of knowledge about hidden variables.[6]

Let us generalize this to a discrete PD first in the conventional way. In this specific example, the random variable X defined on a countable sample space Ω over c possible outcomes is the subdivision of the detection screen in a discrete horizontal coordinate system $x_i, (i = 1, ..., c)$ (for example, a line of pixels of a CCD camera). Let's call them detection channels.

The normalized PD is defined by the probability of detecting a number of n_i photons at those detection channels x_i as $p_i = \frac{n_i}{N}$, with $N = \sum_i n_i$ the overall number of photons measured over all the possible outcomes, in some time interval T, and such that $\sum_i p_i = 1$.

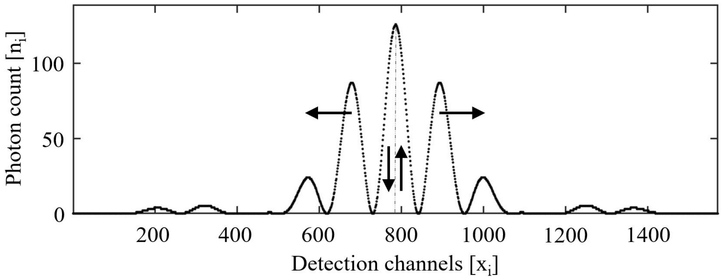

Figure 1: Photon counts for the double-slit experiment. Arrows: Direction of movement.

Fig. 1 shows a particular example. It is the graph of the interference pattern, that is, a PD in terms of an intensity profile represented by N = 20.000 photons for two slits with aperture size $a = 3\lambda$ and distance between the slits of $d = 9\lambda$, with λ an arbitrary wavelength. The sample space over $\left[-\frac{\pi}{4}, \frac{\pi}{4}\right]$ radians is projected on the x-axis in steps of 10^{-3} radians, resulting in $c = 1571$ channels. This is the conventional statistical representation of Young's double-slit experiment after a sufficiently large number of measurements for a sampling time T.

However, an equivalent representation in temporal ordering is also possible. One can represent in an event-time space the overall experiment denoting the ordered time series

$$S = \{t_1^i, ..., t_N^i\}, \quad i \in [1, ..., c = 1571],$$

which are the N time-steps (the N measurements) corresponding to every photon detection at whatever position, that is, whenever the detector

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[6] Contrary to pervasive belief, there are still minority voices claiming that Bell's theorem does not conclusively rule out interpretations of quantum mechanics based on local and/or deterministic ontologies (e.g., see Hance and Hossenfelder 2022.) Here, however, we assume quantum mechanics is a theory without hidden variables.

clicks. One obtains Fig. 2 with the vertical axis representing the same process in time flow.

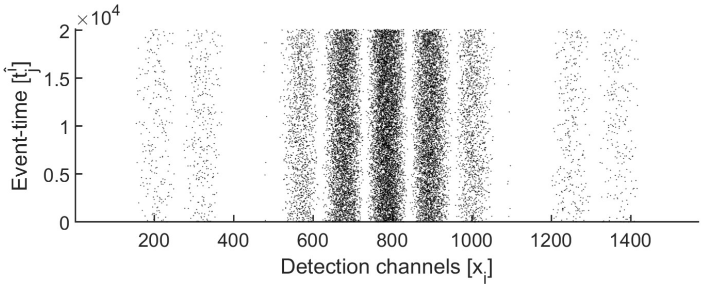

Figure 2: Temporal representation of interference fringes for the double-slit experiment.

This representation contains more information than conventional PDs or the pictures that represent spectral lines. The latter (not to be confused with Fig. 2) are only integrations over time represented by intensity fringes while, in the present case, the time of arrival of each photon is shown. These instants remain unpredictable due to quantum uncertainty. In these processes, not only is the outcome subjected to quantum uncertainty, but so is its temporal dislocation, that is, the times of arrival of the photons during the experiment (even though the average time is a calculable constant of the theory). And, again, the temporal sequence is irrelevant for determining the PD. Permuting or flipping along the vertical axis of Fig. 2 the dots of the interference fringes would have no impact on the pattern of the PD. Their count at each x_i will always be n_i.

Thus, while nature is constrained by the PD, it is free to choose this order without any need to change the PD itself. The question, however, is: How large is that freedom and can it be used to originate anything useful other than yet another random result?

To answer this question, let us imagine a simple toy-model double-slit experimental setup in which each photon detection at a specific interference fringe triggers a dot movement on a screen in a 2D space. For example, consider the PD of Fig. 1 and say that whenever a photon is detected at the secondary fringe left (channels 619-730), this determines a movement leftwards, whenever one is detected at the first half of the central fringe (channels 731–786), this determines an equal shift downwards, whenever one is detected at the second half of the central fringe (channels 787–841), this determines a shift upwards, and whenever one is detected at the secondary fringe left (channels 842–953), this determines a shift rightwards.

For the sake of simplicity and graphical representation, only constant two-unit lengths displacements are chosen. The probability of a turn left or right is about 24% each, while the probability of a move upwards or downwards is about 17% each. This means that in about 82% of cases, a photon hit produces a movement, while in the remaining 18% of cases, the dot remains immobile. This connects physically random quantum events, that is, the order of the position outcomes of photons and its temporal sequence in a double-slit experiment, to the motion of a digital object.

From a statistical standpoint, this process can be investigated with a simple computer simulation. To do so, one must include the temporal dimension in the PD of Fig. 1 with the time series given by Eq. (2), that is, assigning for each photon detected at the i^{th} channel also its j^{th} time of detection, as represented in Fig. 2. This time series can be constructed as the union of time series at each i^{th} channel. The latter is generated by a random generator which distributes n_i events temporally at each i^{th} channel between 0 and T, for every $i = 1, ..., c$ (or, equivalently, distributes randomly the n_i pixels of Fig. 2 along each vertical column). This enables the creation of the sets S_i and their union S of Eq. (3), which then can be temporally ordered.

Once this array of N ordered events is known, the sequence is played out on the graphical interface: A vector is traced along one of the four directions in the temporal ordering of S, according to each photons positions in the above-described fringe intervals. The result is shown in Fig. 3 left.

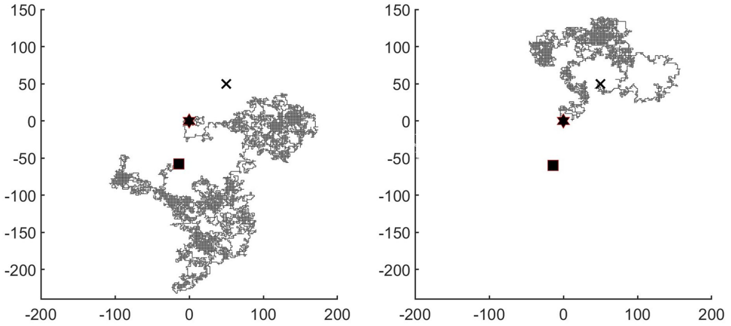

Figure 3: Random walk starts from the starred dot at (0,0) and always ends after 20.000 steps at the squared dot. Left: Target destination x failed, the particle moves until the end of the simulation. Right: Target destination reached, stop at time-step 10091.

The starred dot in the origin is the starting point, while the squared dot is the point of arrival after $N = 20.000$ time steps. The image doesn't suggest any ordering. It is a typical random walk through a 2D surface, determined by the random hit of the photon on one or the other fringe.[7]

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[7] The analogy with the trajectory of a particle subjected to Brownian motion isn't entirely coincidental. Both are random walks. Of course, the underlying physical principles are entirely different.

Directing the path towards a target point, say, the cross at coordinate (50, 50), would be a quite difficult task dependent on extreme luck if we have no control over the temporal sequence of the photons hitting the i^{th} channel at the j^{th} time.

However, suppose a sort of "quantum Maxwell's demon" has control over which photon hits which fringe at what time by permuting the temporal series on each channel as described by the temporal permutation leading from Eq. (3) to Eq. (4), with the only provision that it doesn't alter the number of n_i photons randomly distributed in the time interval between 0 and T. Then it also has control over the random walks. Again, this does *not* alter the PD; it only changes the sequence in time and the channels with which it builds up the interference pattern and, therefore, does not violate any statistical law.

In fact, note that in the context of this experimental toy model the starting and ending points (the random walk from the starred to the squared dot) are always the same. This is because, with whatever random permutation the temporal ordering of the events is realized, the sum of the series of the associated four directional vectors always ends up at the same end point, the square in Fig. 3.[8] Nevertheless, each permutation corresponds to a different path connecting these two points. Also, there exists a virtually infinite number of possible permutations and, consequently, a virtually infinite number of paths ($N!$, to be precise, which for $N = 20.000$ is an outrageously huge number) and with which one can scan the 2D space inside an average radius.[9]

Therefore, while one will never end at the target point, nevertheless, following a Monte Carlo method simulation, after not too many trials it is easy to find a path passing through the desired target point, such as that in Fig. 3 right. This different random walk encounters the target point at time step 10091. (The plots from time steps 10091 to $N = 20.000$ have been omitted for clarity.) This intervention with control over the temporal ordering of the events permutes the vertical photon distribution of Fig. 2 along the time-step ordinate axis, but does not change the profile of Fig. 1.

Thus, a quantum probability law is a constraint on the possible future outcomes and, in this sense, limits the potential future happenings. Nevertheless, if quantum mechanics is, indeed, a theory without hidden variables, that is, the microscopic laws of nature are ontologically indeterministic, then probability laws merely limit the future to a hypothetical self-determining agent-causation, but don't disallow the agent intention to

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[8] Mathematically speaking, this is a consequence of the fact that vector addition in a flat space is a commutative algebra.

[9] This is somehow reminiscent of Feynman's path integral formulation, where classical particle trajectories are replaced by the sum over an infinite number of quantum paths connecting an initial and final point in spacetime.

act freely inside these constraints, eventually also by "moving molecules in directions they were not otherwise going to move".

Moreover, notice how this could potentially offer a different perspective on another long-standing debate in the philosophy of mind regarding the question of the violation of energy conservation in interactive dualism.[10] There is no need to violate conservation laws to actualize a specific history over many potential paths once the demon has access to the temporal unfolding of the quantum processes that determine it. This kind of mental causation doesn't lead to the interaction problem.

4. A Hypothesis for a Libertarian Panpsychist Framework

The numerical simulation in Sec. 3 further underpins Müller's model of an Anscombe box implemented in a computer program. Intentional action at the micro-physical level does not necessarily violate the constraints of micro-statistical laws. However, the difference here is twofold. Firstly, Müller worked with a model that did not venture into an ontology based on a quantum theory without hidden variables. Secondly, and most importantly for our considerations, at this point, the question is: What or who is supposed to be the "demon"?

Müller assumed an agent-causal libertarianism in terms of a rational will acting as an external cause on the physical processes – an agent external to the micro-statistical process that, nevertheless, if operating carefully enough from the outside, could lead to the appearance of regular structures on the box filled with colored particles without violating the statistical laws. This is something he admits is "suggestive perhaps of certain variants of dualism" (Müller 2022). On the other hand, one can also interpret the room left to free agency at the micro-phenomenal level of quantum laws as something suggestive of certain variants of panpsychism, such as micropsychism, with micro-level entities having agential causal powers. This metaphysical perspective is in line with some form of panpsychist conception positing will, consciousness, and a volitional agency as a fundamental primitive finding its way through a reality constrained by the laws of physics.

Panpsychism is the view that consciousness is fundamental and ubiquitous (for recent reviews see Seager 2019, Skrbina 2017, or for a short introduction see Goff 2019). Constitutive panpsychism postulates a fundamental form of consciousness that is ubiquitous throughout nature, not only proper to living beings. It is usually seen from the bottom-up perspective

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[10] For example, in the time-independent Schrödinger equation $H|\Psi\rangle = E|\Psi\rangle$, once the Hamiltonian and the state vector (which, ultimately, determines the probability via the Born rule) are determined, the energy eigenvalue is fixed.

of micropsychism, namely, the view that all macroscopic facts, such as consciousness in biological organisms, are grounded in micro-phenomena involving consciousness. Micropsychists postulate micro-level entities, such as elementary particles, instantiating very basic forms of consciousness. This is contrasted with the top-down perspective of cosmopsychism, a holistic form of panpsychism seeing the universe as a ubiquitous field of consciousness (e.g., see Shani 2015). Varieties of cosmopsychism can be found in the Indian tradition such as the ancient Veda, the Upanishads, and Advaita Vedanta philosophies (for contemporary work on cosmopsychism connecting to the Indian tradition see Ganeri and Shani 2022).

However, micro- and cosmopsychist perspectives need not necessarily be seen as mutually exclusive. Rather, they can be complementary. Even panentheism can be reconciled with panpsychism within an idea where the universe itself is *causa sui* (Brüntrup *et al.* 2020).The universe as a whole is considered a conscious subject, with all conscious entities and properties an aspect of it. Every conscious mind is an individuation of a cosmic mind, as every particle displays some degree of proto-conscious agency. This perspective is reflected in, for example, the Indian mystic Sri Aurobindo, according to whom the universal consciousness individuates into various distinct consciousnesses by limiting itself through a process of "exclusive concentration" (Medhananda 2022).

In a sense, this micro- and macro-scale duality is reflected in quantum physics. Quantum mechanics describes phenomena at the micro-physical level of elementary particles, atomic nuclei, atoms, and molecules. Meanwhile, quantum entanglement is a phenomenon in which two or more particles share the same quantum state over large distances but, once measured, result in locally distinguishable objects with correlated states. Quantum processes were relevant from the first instant of the big bang to the formation of large-scale structures of the universe. Quantum field theory conceives of universal quantum matter and force fields that are subjected to quantum rules (e.g., symmetry principles and conservation laws) and that also display a stochastic character in the form of random quantum fluctuations that locally determine the quantum vacuum state (sometimes also called the zero-point field). These are responsible, for example, for the spontaneous emission of photons from excited atomic states, for radioactive decay, or for quantum tunneling processes – that is, a universal quantum field determines in space and time the outcome of events at the micro-physical atomic level.

We usually do not see anything volitional in this, precisely because of an implicit randomness objection that prevents us from taking this logical step. Yet we have seen that it is possible to circumvent this objection and conceive of a micro-phenomenal libertarian agent causation, such as a particle finding its way toward a target generating a proper quantum random sequence that does not violate the imposed probabilistic laws and is in line with the known laws of nature. This is in line with Heisenberg's idea that the stochastic aspect of quantum mechanics could be seen as the dynamic possibilities of nature, a form of Aristotelian *potentia* that brings a potentiality, or an idea, into actuality (Heisenberg 1958, p. 41).

However, we are also allowed to speculate about libertarian agent causation at the macrolevel over the time series of these events without interfering with the quantum probabilistic laws by conceiving every random quantum fluctuation as the local expression of a pervading cosmic agent. It is not an electron that chooses its spin but the universal consciousness operating through it. Here, we embrace a sort of micro-physical quantum agent-causation hypothesis in which the microscopic quantum field is the expression of a self-determining intentional universal agency. Randomness is not the determinant process, with volition its determination; rather, quantum indeterminacy is the local expression of a global agent-causation determining will. In this sense, a libertarian panpsychist theoretical framework is a viable hypothesis.

5. Conclusion

We have seen how no fundamental logical reason or physical law prevents us from speculating about theories connecting agent-causation and indeterminacy. Upon closer scrutiny, it becomes clear that ample room for free agency exists and this does not alter the profile of a naturally imposed PD. Obeying the quantum laws does not prevent freedom of action.

The understanding of this fact requires essentially a subtle but decisive change in perspective. The randomness objection turns out to be a fallacy based on a lack of awareness of how statistical processes develop over time. We must take into account the temporal dimension of the sequence of outcomes. We can't limit our outlook to the final PD independent of its dynamic development and the ordering of the events in time. In this context, the statistical mathematical aspect of the temporal developments of physical events cannot be ignored.

Inspired by this result, a possible link between quantum indeterminacy and panpsychism has been shortly addressed. In this paper I argue that there is no inconsistency in entertaining a hypothesis of libertarian panpsychism – that is, a theoretical framework conceiving of an agent causation at the micro-level and macro-level, where micropsychism and cosmopsychism appear as complementary aspects rather than opposites.

Quantum effects are usually thought to be relevant only at the microscopic scale due to thermal quantum decoherence. The brain is thought to be a too-warm environment and too large an object to allow quantum phenomena to play any appreciable role. Nevertheless, some have taken seriously the hypothesis that quantum effects may also play a role in neural processes (for some aspects of this see Adams and Petruccione

2020). For instance, some contemporary libertarians suggest that human decision-making may be traced back to an indeterminism at the neuronal level that might be sensitive to quantum indeterminacy (e.g., Kane 2012a). Meanwhile, there is extensive literature in the field of quantum biology (for a review see Youngchan *et al.* 2021).

While all these approaches seek quantum effects in matter, the present approach considered quantum indeterminacy itself as the expression of an agent-causation determining will. If true, this would also imply that what appears to be pure randomness – that is, just noise – could hide a creative power. Inside the domain of classical physics, this is what biologists begin to suspect. Stochastic fluctuations during development might be a deciding factor for non-genetic sources of variation and diversity in anatomical and behavioral traits (see, e.g., Eldar and Elowitz 2010, Bierbach *et al.* 2017, Linneweber *et al.* 2020). Noble and Noble (2018) even conjecture that organisms may "harness stochasticity" to have agency and make novel choices. Contrary to common wisdom, noise and randomness in living systems can play a functional role in biological processes (Roy and Majumdar 2022).

Whether microscopic quantum stochastic phenomena might be amplified up to a macroscopic scale, remains a matter of speculation to date. Nevertheless, it was a conjecture that some of the founding fathers of quantum physics were actively pondering. It dates back to the times of Arthur Eddington, Arthur Compton, and Pascual Jordan. (For an overall historical account see Kožnjak 2020). More recent theoretical investigations tend to confirm this to be the case. Boekholt *et al.* (2020) showed that the dynamics of some chaotic three-body systems of stellar size (!) are, on longer time scales, numerically time-irreversible up to the Planck length. This means that even these must be sensitive to quantum uncertainties, leading to the breakdown of the classical Laplacian determinism at all scales. Bandak *et al.* (2024) have shown how spontaneous stochasticity at the molecular level amplifies molecular noise even to the largest scales of turbulence. Since the molecular scale is the interface between quantum and classical phenomena, quantum spontaneous stochasticity might be amplified at the macro-scale as well.[11]

Thus, while quantum coherence needs low thermal noise at low temperatures to survive and scale up to mesoscopic systems, the effects of quantum indeterminacy are not limited by these requirements and can take advantage of the strong sensitivity to small perturbations of nonlinear systems. Thereby, on the base of what has been outlined here, it can link micro-phenomenal randomness with notions of agency in the frame of a libertarian free will ontology. This might not be palpable to

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[11] Indeed, in a preprint, Eyink and Drivas (2015) argue, starting from the same principle of spontaneous stochasticity, that quantum indeterminism persists at the classical limit.

everyone's philosophical inclinations and might put into question the significance and nature of the sourcehood of free will. However, the fact remains that, to date, nothing in the presently known laws of nature prohibits us from entertaining such a metaphysical standpoint.

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