The Interaction Problem and Mental Causation: A Quantum Field Theoretical Perspective

Abstract

A fundamental issue in the philosophy of mind, particularly within dualist theories, is the distinction between the mind and body as separate 'substances.' The challenge lies in elucidating how an immaterial or unphysical mind can causally interact with a physical body or its brain states, considering that they seemingly belong to fundamentally different ontological categories. Questions regarding mental causation often operate under assumptions rooted in a macroscopic worldview based on our everyday intuitions and classical physics, which we believe have clear and defined meanings. However, upon closer inspection within an extended quantum field theoretical context, these concepts lose significance. When viewed through the lens of modern physics, the conceptual categories defining this debate acquire more complex nuances than we might initially assume. In light of these clarifications, a new understanding of mental causation is presented that reconciles the dualist perspective with the probabilistic nature of quantum mechanics.

Keywords: interaction problem, mental causation, philosophy of mind, metaphysics, mind-body problem, interactive dualism, cognitive science, psychology, neuroscience.

Introduction

Although contemporary philosophy has largely moved away from the original Cartesian substance dualism, non-physicalist theories remain prominent. Examples include dual aspect monism, panpsychism, cosmopsychism, idealism, substance monism, and various theistic or spiritualist accounts. They contend that the mind is neither reducible to nor entirely dependent on the physical brain or body. Mental properties are understood as non-physical properties, with the body and mind regarded as distinct and separable entities or, at the very least, not reducible to exclusively physical properties.

Despite their differences and nuances, these theories within the philosophy of mind share a common rejection by physicalist mind-body identity theories, which posit that physical processes or properties can fully explain mental phenomena. This is because asserting a fundamental distinction between the mental and the physical implicitly endorses some form of 'interactionism' or 'interactive dualism'—the notion that the body and mind causally interact with one another despite being fundamentally different in nature. The same question applies not only to the mind but also to any entity or purportedly metaphysical substance, such as a soul, spirit, or 'immaterial' or 'unphysical' consciousness. This leads to one of the most enduring philosophical challenges, known as the 'interaction problem' or the 'problem of mental causation,' framed in 1643 by Princess Elisabeth of Bohemia, who presented a pointed challenge to Descartes regarding his Meditations on First Philosophy: *"Given that the soul of a human being is only a thinking substance, how can it affect the bodily spirits in order to bring about voluntary actions?"* (Shapiro, 2007).

In more modern terms, the issue can be expressed by asking how putatively non-physical mental states—such as beliefs, desires, and intentions—can exert any causal influence in a physical world governed by physical laws. The dualist causal heterogeneity problem arises: If mental properties, states, or substances are radically heterogeneous from material objects and physical forces, they lack the commonality necessary for interaction. If the mind is immaterial, it remains unclear how it can causally interact with a material body without violating fundamental principles of physics and maintaining metaphysical coherence. For an overview, see (Robb, 2023) and (Cucu, 2022), the classic work by Popper and Eccles (Popper, 1977), or (Lindahl, 1994), (Libet, 1994), and (Libet, 2006).

Another common objection to the concept of mental causation, dating back to Leibniz[1], is that such interactions would violate the principle of energy conservation. If physics encompasses all interactions among particles within the brain, then an immaterial mind influencing the brain's biochemistry would introduce a novel form of interaction at the microscale, ultimately violating the principle of energy conservation. For this longstanding dispute, see (Averill, 1981), (Larmer, 1986), (Kim, 1993), (Wilson, 1999), (Montero, 2006), (White, 2016), (Cucu, 2019), or (Seager, 2022).

Given that, despite centuries of debates, these fundamental issues remain unresolved and no consensus has been reached, the interaction problem is frequently invoked as a knockdown argument against any form of dualism and as a compelling rationale in support of physicalist mind-brain identity theories.

This paper has two main aims. First, it seeks to highlight various semantic ambiguities related to the categories involved in the interaction problem, thus providing conceptual clarity in light of modern physics. The first part will emphasize the distinction between what we consider 'material' versus 'immaterial' and 'physical' versus 'unphysical,' clarify what an 'interaction' is according to the standard model of particle physics, and question what an extended versus non-extended 'substance' could possibly mean in the context of contemporary physics, particularly quantum field theory (QFT). The second part will examine a proposal for a principle of mental causation, grounded in the conceptual framework established in the first part, with particular attention paid to the stochastic phenomena associated with quantum effects.

I. When Words Matter: Pursuing Conceptual Clarity in the Light of Contemporary Physics

1. What Does 'Immaterial' Mean?

From a physics perspective, the interaction problem is frequently articulated using ambiguous and potentially misleading terminology. For example, the inquiry regarding how an 'immaterial' mind can causally interact with a 'material' body implies a clear and well-defined distinction between the two or at least suggests that this distinction is self-evident and requires no further elucidation. Eventually, these opposing categories become conflated with the related notions of 'physical' versus 'unphysical.' However, at least from the perspective of the physical sciences, this conceptual ambiguity prevents a deeper understanding of the subject.

In physics, the term 'material' encompasses all entities composed of matter—specifically, those that possess mass. Mass serves as a measure of inertia, which is the property of a particle or body that enables it to resist changes in its state of motion. A massive particle can always be accelerated or decelerated, moving at speeds less than the speed of light. In contrast, light has no rest mass—i.e., it lacks inertia (it does not undergo acceleration or deceleration)—and always travels at about 300,000 km/s in whatever frame of reference. In the framework of special relativity, the concept of rest mass takes on a more abstract role as a relativistic scalar invariant. However, one does not need to pin down rigorous definitions to recognize that

[1] See the introduction of (Pitts, 2019) and references therein for a historical overview.

physics is replete with entities that are 'immaterial' yet nonetheless real, concrete, and not 'unphysical.'

For example, light is a massless—that is, 'immaterial'—electromagnetic field that propagates throughout space and interacts with material particles or bodies. From the perspective of quantum electrodynamics (QED), electromagnetic waves are mediated by light particles—the massless gauge bosons, commonly known as photons—which are immaterial entities that, as we know from everyday experience, have considerable causal power over material ones.[2]

The same can be said about the action of a gravitational field. Gravity is a massless force field that interacts with material objects. The causal influence of this 'immaterial' field on massive bodies, such as planets and stars, is well established. In general relativity, gravity is represented as a curved 4D differentiable spacetime Riemannian manifold whose curvature is determined by mass or energy and along which everything follows the shortest geodesic path. Taylor and Wheeler summed it up concisely: *"Spacetime tells mass how to move, mass tells spacetime how to curve"* (Taylor and Wheeler, 1992). The status of the gravitational force relative to the three other fundamental forces (the electromagnetic and the strong and weak nuclear forces) is a matter of some debate; however, the relevant fact is that a material object can interact with another material object without direct contact by warping its surrounding vacuum.

The question of how causal influence can occur between material bodies without direct contact through empty space, solely through an immaterial field or an even more ethereal notion of spacetime curvature, is not a novel philosophical issue. When Newton was asked about the nature of gravity's 'action at a distance,' his official response in the Principia was: *"Hypotheses non fingo"("I do not frame hypotheses")*. However, his private correspondence reveals that framing hypotheses was likely one of his major occupations: *"That gravity should be innate, inherent, and essential to matter, so that one body may act upon another at a distance through a vacuum, without the mediation of anything else, by and through which their action and force may be conveyed from one to another, is to me so great an absurdity that I believe no man who has in philosophical matters a competent faculty of thinking can ever fall into it. Gravity must be caused by an agent acting constantly according to certain laws; but whether this agent be material or immaterial, I have left open to the consideration of my readers"* (Cohen, 1978).

Unfortunately for Newton, for centuries, nearly all scientists with a "competent faculty of thinking" have accepted this "great absurdity" without further questioning it.

The same phenomenon presents itself at the microscopic scale in the realm of nuclear forces. The stability of matter relies on the strong nuclear force, which binds quarks through asymptotic confinement to form protons and neutrons in atomic nuclei. This interaction is mediated by massless gluons, the gauge bosons responsible for the strong nuclear force.

The fact that massless fields can interact with material particles rarely raises concerns because modern physics takes a pragmatic approach, accepting this state of affairs as a given. Instead, it focuses on the mathematical formalization that allows for empirically verifiable predictions, largely overlooking the philosophical issues regarding how immaterial entities can causally affect material objects. No explanation regarding the principle of causal heterogeneity is deemed necessary.

[2] One could argue that, according to the mass-energy equivalence principle, matter and energy can be converted into one another (e.g., during annihilation processes between particles and their antiparticles); their ability to interact might stem from a shared commonality at a fundamental level. However, adopting this perspective could provide more reason to embrace a panpsychist viewpoint, positing that mind and matter share a similar equivalence. This interpretation renders the interaction problem no more problematic than any interaction within physical theories.

Yet, for some reason, when a similar conceptual issue arises in the philosophy of mind—specifically regarding how an immaterial mind could interact with a material brain or body—it is presented as a seemingly insurmountable objection against any form of dualism.

Of course, one might object that the central issue in the debate over mental causation should not be framed as a conflict between 'material' and 'immaterial' physical entities. Instead, it involves the question of how an 'unphysical substance' can influence a 'physical substance.' Indeed, that's what we will see next.

However, the terminological clarification was necessary. It underscores that when we deal with more foundational philosophical questions, category conflation can lead to conceptual confusion. It also highlights that a broader interaction problem has existed throughout the history of science yet has not been considered particularly worrisome.

2. What Does 'Unphysical' Mean?

The same question arises regarding the distinction between what is meant by something being 'physical' versus 'unphysical' or 'metaphysical.' When discussing whether a non-physical mind can influence a physical brain, we cannot exempt ourselves from clarifying the distinction between what 'physical' and 'unphysical' mean. It is precisely the nature of this distinction, along with the more or less unaware premises underlying it, that determines the character of our reasoning, conjectures, and conclusions. If such categories are based solely on a vague commonsense understanding of everyday experience, then speculations about the mutual interaction of physical and unphysical entities, or about causal closures, could become misleading or devolve into mere wordplay.

For example, an unaware but not uncommon fallacy lurking behind the debates on mental causation is that of positing a priori that anything that cannot interact with the physical world is considered 'unphysical' and then asking how an unphysical mind could interact with a physical body. This results in circular reasoning such that the conclusion is implicitly assumed in the premise. While coming from the via negativa, defining physical as anything that is not mental or experiential merely reinforces the notion of the mind as non-physical and does not clarify its causal relationship.

On the other hand, there is no universally accepted definition of what constitutes 'physical,' nor is there a clear distinction between physics and metaphysics or an agreement on the foundational doctrines of physicalism. The term 'physical' varies in interpretation depending on the context and discipline, such as science, metaphysics, philosophy of mind, and philosophy of science. This definitional challenge is not new; its history is encapsulated in Hempel's dilemma (e.g., see (Stoljar, 2010), (Ney, 2014), (Elpidorou, 2018), (Judish, 2007)).

Nonetheless, while one could agree that physics alone cannot define the 'physical' (Crook and Gillett, 2001), one could also say that it helps us gain conceptual clarity.

The aim of this section is not to provide a definitive answer, as, even in physics, there is no unique and rigorous characterization of the physical appropriate for mind-matter conjectures. Instead, the aim is to clarify the quantum field theoretical foundations that physics uses to describe the physical world while acknowledging its limitations. Investigating how far physics can lead us might allow us to expand (or restrict) or further define the boundaries and foundations of other metaphysical non-physicalist theoretical frameworks, an example of which I will present in the second part.

Conventional physics textbooks do not define physics in contrast to metaphysics, except perhaps through a historical note that the term 'physics'—and, thus, 'physical'—originates from Aristotle, who coined it to mean "the study of Nature." Nonetheless, a characterization in line with contemporary science could be to describe as 'physical' anything that can be empirically verified, existing in space and time, and governed by the laws of physics. Spacetime, matter (or energy, according to the mass-energy equivalence), and the laws of physics (or causality) are the ingredients of the typical understanding of classical mechanics, which is often assumed in dualist debates.

Meanwhile, in physics, the term 'unphysical' does not carry a metaphysical implication; it usually refers to meaningless solutions of differential equations, such as negative or infinite energy states, complex-valued lengths or time intervals, probabilities exceeding one, the violation of conservation or symmetry principles, etc.[3] An ‘unphysical solution’ is a mathematical limitation of the formalism describing impossible physical processes or nonexistent entities and does not hint at anything metaphysical.

Therefore, if we accept this definition and consider the mind to be an unphysical substance, we either refer to something that does not exist—a self-negating paradox—or imply something that transcends spacetime, matter, energy, and the laws of physics. Once again, this leads us to assume an interactive impossibility from the outset, resulting in the same circular reasoning mentioned earlier.

However, if we are looking for the most fundamental primitives of physical reality from the perspective of modern physics, this is an outdated view.

Firstly, as we have seen in the previous section, physics is full of immaterial things that aren’t made of matter. Matter isn’t fundamental and must be replaced by something else. The contemporary theory that describes reality at the most fundamental physical level, which is the standard model of particle physics based on QFT, describes matter, energy, forces, and all interactions with quantum fields.

What is a quantum field in QFT?[4]

Technically speaking, quantum fields are operator-valued distributions defined in spacetime that operate on a Hilbert space (or a Fock space in the context of multiparticle systems). Specifically, quantum field operators act at a given point in space and time and can be expressed in terms of creation and annihilation operators, which correspond to raising or lowering a particle’s state. These fields can be scalar fields (such as the Higgs boson) or vector fields with integer spin (bosons like photons and gluons) or half-integer spin (fermions, such as quarks and leptons). Within this theoretical framework, quantum fields are modeled as the sum of quantized harmonic oscillators (field modes), with particles representing wave-like quantized excitations of the ground state (the vacuum in its unexcited condition), with a distinct quantum field assigned to each type of particle (e.g., the photon corresponds to the electromagnetic field, while the electron is associated with the Dirac field, etc.).

However, we need not engage in technicalities; for our purposes, we can consider quantum fields to be the foundational fabric of what we refer to as 'physical' reality. In this framework, particles can be intuitively visualized as traveling-wave perturbations of the respective particle field parametrized over a spacetime manifold (sort of localized excitation or fluctuation, just imagine vibrating 'bumps'), with interactions occurring when these excited states couple with one another. (Section I.3 contains more on the nature of interactions).

Secondly, while in philosophy the concepts of ‘laws of Nature’ and ‘causality’ have also given rise to longstanding debates, in QFT the laws of physics are determined by symmetry conditions, and causality refers to the interaction of fields constrained by a relativistic microcausality condition. (No influence can travel superluminally.) All the laws of physics

[3] However, it is standard practice to utilize negative energy states for the description of potentials. Moreover, history shows that, eventually, such solutions might turn out to be physical if adequately interpreted. The paradigmatic example is the negative energy states predicted by Dirac’s equation, which are now interpreted as representing antiparticles.

[4] Whether the ultimate ontology of QFT is based on particles, fields, quanta, ‘bundles of properties,’ or whatever other kind of noumenal entities is debatable, e.g., see (Kuhlmann, 2010). However, despite the existence of various interpretations, the mathematical formalism of QFT is unambiguously articulated in the language of fields. Given the wider support for this perspective, I will adopt the field as the conceptual foundation of reality in QFT.

emerge from the requirement of symmetry principles—that is, the principle of covariance, global and local gauge invariance, and spontaneously broken symmetries. Ultimately, what we call the 'laws of Nature' and 'causality' boil down to symmetry principles involving quantum field operators constrained by algebraic rules (canonical commutation relations) imposed to preserve the wave-like aspect of the fields and particles.

Thus, according to QFT, spacetime and (wave-like) quantum fields subjected to symmetry principles and of relativistic causality are what contemporary physics considers 'physical' at the most fundamental level. In contrast, whatever transcends spatial and temporal relationships and can't be modeled by a quantum field subjected to these symmetry and causality principles may be classified as 'unphysical.'

That said, this viewpoint is also not without ambiguities.

Interestingly, QM and QFT inherently possess a Platonic flavor, with unobservable abstract entities that are not directly observable or verifiable nevertheless being part of the physical theory. Examples include the ambiguous epistemic vs. ontological status of the wavefunction, the ghostly appearance and disappearance of virtual particles in the quantum vacuum, and the non-unitary evolution resulting from the measurement process (the measurement problem and the infamous 'collapse' of the wavefunction). Opinions vary widely on whether these entities or processes should be regarded as 'physical' or 'real' beyond useful mathematical abstractions.

A clear example of this situation is the well-known wave-particle duality, in which particles like electrons and photons display both wave-like behaviors (such as interference and diffraction) and particle-like behaviors (such as localized interactions on detectors). In QM, particles' states are described by the wavefunction, while in QFT, this duality is reconciled by viewing particles as discrete excitations of underlying continuous wave-like quantum fields. However, the ontology of these concepts remains ambiguous. Although wavefunctions and quantum fields are the fundamental entities that describe reality, our observations are limited to the detection of point-like interactions impacting detectors rather than waves or fields. The question of whether wavefunctions or operator-valued fields should be regarded as 'real' and 'physical' objects or merely as abstract mathematical tools devoid of ontology is ultimately a matter of personal philosophical preference.

Then, while the microcausality condition is preserved, long-distance correlations can arise between space-like separated entangled particles. This means that quantum theory is inherently non-local, which complicates the classical understanding of spatial relationships. More on this later.

A further ambiguity arises when we consider that QFT is embedded in a special relativistic framework where space and time are not absolutes but relative. If we consider anything that cannot be described in spatiotemporal terms as unphysical, should we then view the interior of a black hole beyond the event horizon—where our understanding of spacetime breaks down—as 'unphysical'? QFT is not a general relativistic theory, so we cannot definitively answer this question. However, it is unlikely that general relativistic—let alone classical—notions of spacetime survive in such extreme conditions. This makes the characterization of physicality tied to spatiotemporal concepts even more questionable.

Meanwhile, some contemporary efforts to unify quantum physics with general relativity into a theory of quantum gravity are raising questions about the nature of space and time themselves. Rather than being fundamental structures of reality, they might be emergent properties arising from a deeper layer of existence that transcends spatial and temporal dimensions. If a theory of quantum gravity were to be successfully confirmed—one that views spacetime not as fundamental but as an emergent property—would the criteria used to differentiate between 'physical' and 'unphysical' entities still hold?

Taken together, these aspects of QM and QFT should prompt us to take some precautions regarding the conceptual categories we employ when we speculate about unphysical minds interacting with physical bodies. The categories with which we discriminate between what is physical and unphysical are ideas tied to our subjective perceptions of reality and are mental abstractions that are useful for navigating our everyday lives; however, they have little to do with the more fundamental structure of reality. Nonetheless, despite its ambiguities, QFT provides a stronger foundation for constructing models of interactive dualism that are more consistent with current scientific knowledge.

3. What Are ‘Interactions’ and ‘Substances’?

Given that the problem of mental causation contemplates the interaction between minds and bodies or brains, it might be helpful to clarify what ‘interaction’ means in contemporary physics. Particularly in QFT, this concept differs significantly from our ordinary intuition.

Interactions in QFT are represented as the coupling of fields in scattering processes. They are defined by the higher-order (non-quadratic) terms in the Lagrangian density (a mathematical function that summarizes the dynamics of a physical system), representing nonlinear couplings between fields—that is, the exchange of energy and momentum. These are useful for describing scattering processes in which particles deflect each other, eventually producing new particles in creation or annihilation processes. Meanwhile, weak force interactions determine decays, with unstable particles transforming into lighter ones.

The interaction Lagrangian determines the scattering matrix, or S-matrix, which is a mathematical object that encodes the probabilities for all possible initial particle states to scatter into final particle states, as a weighted sum of all possible ‘histories.’ Computing its matrix elements provides a way to calculate scattering amplitudes—that is, the transition probabilities from an initial state to a final state of each of these possible 'histories’—for which perturbative expansion terms are graphically represented as Feynman diagrams. These are pictorial representations of the interaction by an exchange of virtual particles. Symmetries constrain the possible forms of the interaction Lagrangian and, thereby, determine the structure of these interactions.

The strength of the interaction is quantified by a coupling constant. For instance, in the interaction between an electron field and a photon field, the fundamental electric charge of the electron, denoted as e, serves as the coupling constant in quantum electrodynamics. Meanwhile, in a Feynman diagram, the electromagnetic force is represented as a virtual photon exchange between charged particles. Fig. 1 illustrates a scattering process, with time flowing along the vertical axis, between two electrons (depicted as straight lines) through the exchange of a virtual photon (shown as a wavy line). Virtual particles can be considered temporary disturbances of a field that exist for only extremely short time intervals during the interaction. They are called 'virtual' because they are a mathematical tool used in perturbation theory, not measurable entities corresponding to stable, propagating, physical objects.

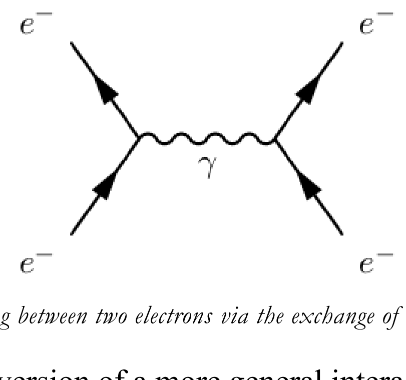

Fig. 1 Scattering between two electrons via the exchange of a virtual photon.

Fig. 2 presents a simplified version of a more general interaction process as conceived of in QFT. Two incoming particles (represented by straight lines p_1 and p_2) scatter in a spacetime region (the grey circle), where they exchange energy and momentum through a complex process, resulting in two outgoing—potentially different—particles (the continuous lines p_3 and p_4.) The energy-momentum transfer, mediated by the exchange of virtual particles (which are not necessarily virtual photons), can occur in various ways. The first possible history (first order scattering amplitude) is that of Fig. 1, but an infinite number of other possible interaction schemes is possible.

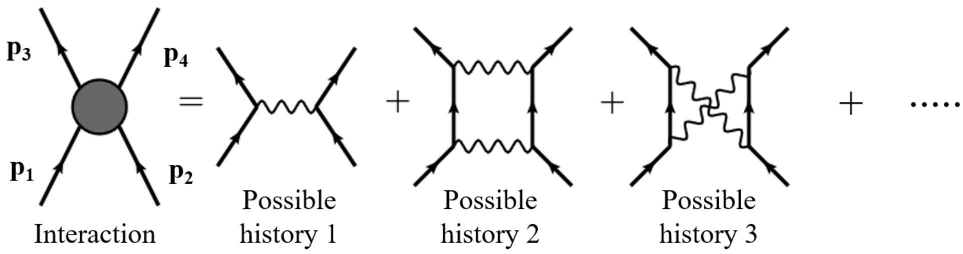

Fig. 2 In QFT, an interaction is represented as the sum over all possible scattering processes.

This counterintuitive conception of what an interaction is in QFT, while perfectly coherent from a theoretical and mathematical standpoint and at the basis of one of the most successful theories of all time (namely, the standard model of particle physics), highlights that we shouldn't interpret these graphical representations as having any ontology other than fictions that serve our naïve intuition. However, we must recognize that our everyday experience of 'interactions' in terms of substances 'colliding' or 'contacting' each other is merely a mental abstraction based on subjective sensations. This conception, which more or less implicitly often still survives in the interactive dualism debates, lacks significance at a more fundamental level; it arises on a macroscale from a collective phenomenon of countless microscopic quantum scattering processes. There is no solid, point-like particle that bounces off another point-like or extended rigid object, nor is there a classical understanding of an extended continuous substance occupying a definite volume of space. There is only a complex interaction of fields that manifests through a localized exchange of forces in space and time.

From this viewpoint, even the classical notion of 'matter' as a substance becomes problematic. Matter itself represents an expression of a force field, always reducible to an exchange of forces—specifically, the mutual interactions of these fields. Positing matter in a definition of what must be considered 'physical' is misleading; force fields are more fundamental.

Notice that Nature doesn't provide a solution to the heterogeneity problem; it simply ignores it. In QFT, quantum fields do not need to have anything in common to interact with each other. For example, an electron, which is a localized excitation of the electron field, interacts with a photon, the excitation of the electromagnetic field. In contrast, gluons (the carriers of the strong force) and the W^+, W^-, and Z^0 gauge bosons (the carriers of the electroweak force) couple with quarks but not with electrons and all the other leptons. On the other hand, photons, despite their commonality, do not couple with one another.[5] What determines these interactions involves a complex series of factors, such as particle charge, the gauge symmetries governing the scattering process, higher-order correction terms in the Lagrangian, etc. However, aspects like 'commonality,' 'sameness,' and 'diversity' of the fields do not play a role. At the most

[5] However, they do weakly interact in very high-energy scattering processes.

fundamental level, physical reality does not align with our classical understanding of how ‘substances’ interact.[6]

And what qualifies as ‘substance’?

In this framework, the notion of ‘substance’ also tends to become vague or even redundant. The problem of mental causation investigates how two fundamentally different substances can exert causal influence on one another. However, it often obscures the lack of philosophical consensus regarding the definition of ‘substance.’ This debate is as ancient as philosophy itself, tracing its origins from Aristotle to post-Roman Neoplatonism, encompassing the contributions of Arabic and Eastern traditions, and continuing through thinkers such as Locke, Hume, Kant, Spinoza, and Descartes. For a brief introduction, see (Hoffman and Rosenkrantz, 2009). Contemporary discourse has witnessed a resurgence of neo-Aristotelian hylomorphic interpretations (e.g., (Simpson, 2024)).

Broadly speaking, the ontology of substance can be conceptualized as an underlying entity, substratum, a haecceity, or noumenal Kantian ‘thing in itself,’ distinguished from its attributes and properties. It signifies something invariant that nonetheless maintains properties subject to change.

The curious aspect of QFT is that the ‘substances’ involved (massless or massive particles) and their interactions are ultimately both manifestations of quantum fields. In QFT, all interactions are understood as being the exchange of force-mediating particles between other particles, both of which are described as excitations of fields. No clear distinction exists between substance and interaction; both are made of the same object.

Thus, if we overlook the fundamental aspects of physical reality that modern science highlights and entertain ourselves with no better-defined ‘interactions’ between physical and metaphysical ‘substances’ while adhering to conventional everyday life interpretations of these terms or have in mind a 17th- to 18th-century physics, we will likely encounter persistent conceptual challenges and paradoxes.

QFT is certainly not the final theory; a theory of quantum gravity is likely to offer deeper insights into the nature of reality. Nevertheless, it is the best model we currently have, and its conceptual foundations can't be ignored in metaphysical speculations regarding interactions between 'immaterial,' 'unphysical,' and 'non-extended' minds and 'material,' 'physical,' and 'extended’ substances.

4. What Is a ‘Non-Spatial’ Substance?

The debate framed within Cartesian dualism becomes equally vague when we address how a non-extended mind—meaning a mind that is ‘non-spatial’—can interact with entities existing in a spatial realm. What might initially appear to be a well-defined question loses clarity when examined through the lens of the non-local nature of QM.

Let's explore the most distinctive quantum effect in this regard: quantum entanglement. Quantum theory states that when entangled particles undergo a measurement process, their previously non-separable pure state is instantaneously projected into a mixed state of distinguishable particles—i.e., the particles acquire definite properties. This results in an instant correlation (or anti-correlation) between the particles, even if they are light years apart—as if there were no extension separating them. This non-local aspect of QM famously prompted Einstein to complain about “spooky actions at a distance.”

[6] That said, it should be noted that, while the current standard model of particle physics does not conceive of a singular quantum field, as it assigns a separate quantum field to each type of particle, one can expect that a future theory of quantum gravity might unify these fields as specific states of a single universal quantum field. This would reintroduce a sense of commonality that aligns with our intuitive understanding of causal influences. On the other hand, it would also suggest viewing reality through the lens of substance monism instead of substance dualism. An investigation of the interaction problem from the perspective of a Spinozist worldview within modern QFT would be worthy of more attention.

Thus, whether these non-local quantum phenomena can be promoted to 'non-spatial' phenomena is debatable. Quantum entanglement correlates measurements across space, yet it describes a physical process that cannot be framed within the classical or relativistic concepts of spatio-temporal causality. The holistic character of long-range correlations between coherent states doesn't fit into our conventional notions of spacetime locality.[7]

Consequently, in the context of modern physics, this becomes one more reason for caution. The question is: Can a non-local mind qualify as 'non-spatial' or 'non-extended'? This is a mind that, while not situated in space, would still have the causal power to determine long-range correlations between physical systems.

Several objections to this hypothesis can be raised.

Mind-matter causality often relies on the principle of transference, which posits that for A to be causally effective on B, A must transfer something to B (Hoffman and Rosenkrantz, 1991). Causation appears to require something like a flow of energy or a force interaction between objects to produce physical effects. However, physical forces, along with energy, linear or angular momentum, spin, and other dynamical variables, are meaningful only within a context involving spatial relations parameterized over time. A context that would not only reintroduce the ontology that the hypothesis seeks to transcend but also violate conservation laws, particularly principles of energy and momentum conservation. This is why, since the time of Schrödinger, critics, including popular physicists like Sean Carroll, have argued that incorporating mental causation would necessitate a modification of the natural laws of physics (Schrödinger, 1951), (Carroll, 2021). Meanwhile, some authors argue that the principles of energy and momentum conservation might not be the inviolable axioms they are commonly thought to be (Cucu and Pitts, 2019), (Pitts, 2020), (Pitts, 2022).

Additionally, one should always keep in mind that non-local quantum phenomena, which correlate the observable properties of particles, cannot be used to exchange information. Although a measurement or interaction can cause a state projection that correlates the states of distant particles, the specific state into which each particle will be projected is an exclusively stochastic process. As a result, no useful signal can be sent from one particle to another.

The second part of this paper will show how these objections, while technically correct, can be circumvented by the inherent stochastic aspect of QM and QFT.

II. Causality Without Interactions

Now that we have clarified the context in which the interaction problem must be thought to be embedded according to our current understanding of the physical world, we can see new avenues for conceiving of mental causation. When analyzing principles of mind-matter interaction within a quantum theoretical framework, we cannot abstract from the fact that the concept of physical causality in quantum physics is significantly different from its classical and relativistic counterparts due to its stochastic nature (except for the aforementioned microcausality precept).

In a Newtonian (or should we say 'Cartesian'?) universe of classical mechanics, as well as within the realms of special and general relativity, the causal structure is defined by differential equations that determine the dynamical evolution of a system's physical state. Once the initial and boundary conditions are fixed, the solutions uniquely specify, say, the point-particle's state of motion, its potential and kinetic energy, etc. Consequently, the system's evolution over time is predetermined—that is, the present state will uniquely determine the future state, leaving no room for a 'freedom to choose otherwise.'

[7] One of the interpretations of QM is the Transactional Interpretation of QM, which suggests the existence of a quantum substratum of a pre-spatiotemporal and pre-empirical realm of possibilities rather than that of a mechanistic causal determinism mappable onto a Cartesian coordinate grid (Kastner and Kauffman, 2018), (Kastner, 2022).

In QM, the situation is considerably more subtle. Essentially, quantum stochasticity reflects the wave-like nature intrinsic to QM and QFT. It underpins quantum superposition states, interference phenomena, and, crucially, the principles of quantum uncertainty that characterize indeterminate quantum states. The wave-like characteristics of particles and fields are imposed by the first quantization in QM (treats the single particle as a wave) and second quantization in QFT (extends to infinite degrees of freedom–that is, many particles). The wave-particle duality and uncertainty relations are inherently embedded into their frameworks because the fields adhere to wave equations such as the Schrödinger, Klein-Gordon, and Dirac equations.

Therefore, the differential equations that govern the unitary time evolution of a quantum state are 'deterministic' only in a statistical sense; they uniquely specify the wavefunction (or state vector) and, consequently, the probabilities derived from the Born rule, not which event will be observed next. The Schrödinger and Dirac equations are fundamental physical laws that dictate the dynamical evolution of a quantum system over time, in terms of a unique solution leading continuous probability density functions or discrete expectation values. These solutions furnish probabilities over a set of possibilities, not a single actuality. While the timing and nature of single events—that is, the instant of the state vector projection (or 'collapse' of the wavefunction)—are constrained probabilistically, they are not uniquely predetermined by the past conditions. This means there is still room (limited by statistical variance), which raises the possibility that Nature may 'choose' which events within a state of potentiality will manifest into actuality and when that will happen.

For example, consider the radioactive decay of the element Bismuth-212. A single Bi-212 atomic nucleus has a lifetime of about an hour, which means that after an hour, there is a 50% chance it has decayed and a 50% chance it has not. However, there is an approximately 16% chance of decay within the first 15 minutes and a roughly 3% chance that the nucleus is still intact after five hours. Moreover, there are two competing decay modes: a 64% chance of decaying via a β^--decay into Polonium-212 and a 36% chance of decaying via α-decay into Thallium-208.

What determines which of the possible 'histories' will take place and when? According to standard quantum theory, the answer is that, apart from the stochastic constraints, there is no other underlying cause or local hidden variable determining the time and kind of decay; it is simply a random occurrence. If we assume quantum theory is a non-local theory without hidden variables, we might even argue that there is an inherent non-spatial, and 'acausal' or 'self-causal' kernel within quantum phenomena. Heisenberg's uncertainty principle, which imposes limits on our ability to determine simultaneously a particle's position and momentum, or the energy-time uncertainty relation, which highlights the energetic indefiniteness of quantum states with finite lifetimes, are not merely epistemic limitations; they are ontological aspects of quantum phenomena. The timing of the next nuclear decay and the specific eigenstate into which the wavefunction will collapse are unpredictable, limited only by the constraints of quantum uncertainty. This is not because of our lack of knowledge of the causal principles underlying this uncertainty; rather, it is because of the inherently random nature of quantum phenomena. Physicists often refer to a theory in which stochasticity lacks hidden variables, without delving into the philosophical implications.[8] However, quantum uncertainty is framed in terms of potentiality rather than spontaneous events, let alone the deterministic evolution of actualities (Kastner and Hoffman, 2018), (Kožnjak, 2020b). This interpretation might not resonate with

[8] Some might favor interpretations of QM, such as the Many Worlds Interpretation, de Broglie-Bohm mechanics, superdeterminism, or other speculative frameworks with local hidden variables that at least partially recover our everyday classical spatiotemporal realism. Analyzing the issues raised in this paper from the perspective of all these interpretations would exceed the paper's scope and space limitations. Instead, I will align with those interpretations that endorse a non-local, ontic indeterministic realism without hidden variables.

the philosophical commitments of physicalists and naturalists due to its teleological nuances, but it lends itself to metaphysical frameworks of mental causation.

The diverse and seemingly insurmountable conceptual metaphysical difficulties appearing in the classical physical context can be resolved at once if we recognize that the state of a system depends not only on the interactions that determine its evolution but also on the order in which these interactions occur. The history of the world is shaped not only by the events that have influenced it but also by the sequence in which these events have unfolded. The kinematic order of events is just as causally significant as the events' dynamical type and magnitude.

A straightforward example of this circumstance is the motion of an object in space resulting from stepwise changes in direction and distance. We can represent its path using an ordered set of vectors with random orientations and lengths in a 2D Cartesian coordinate system, as shown in Fig. 3. The left plot displays 100 vectors with random directions and lengths defined by a standard normal Gaussian distribution. The right plot depicts three possible random walks obtained by summing these vectors. Each walk begins at the coordinate origin (the yellow star at (0,0)) and consistently ends at the same point (the yellow square).[9]

However, the sequence in which the vectors are chosen leads to different paths. The blue, red, and green random walks in the right plot of Fig. 3 comprise the same vectors as in the left plot but are arranged in three distinct orders. While the starting and ending points are the same, the paths are unique due to the different sequences of vector selection. The number of possible paths that can be realized corresponds to the number of permutations of the elements of the vector set, which is proportional to N!. For N=100, the number of possible histories is enormous, nearly infinite.[10] Consequently, the very same events can lead to vastly different histories depending on the order in which they occur.

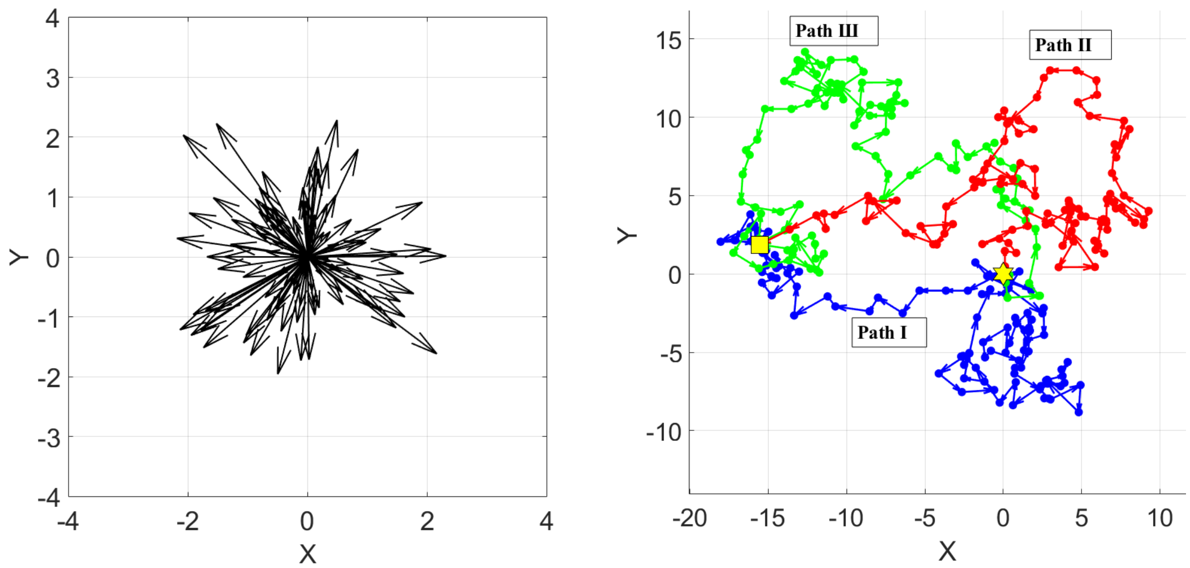

Fig. 3 Left: Randomly oriented vectors. Right: Three paths resulting from the summing of all vectors with three different permutations.

Fig. 4 displays the histograms of the X and Y coordinates of all vectors. With only 100 vectors, the Gaussian distribution is only vaguely recognizable. The decisive aspect is that any

[9] It should not be surprising that the combination of randomly oriented vectors with varying lengths starting from the same point always end up at the same endpoint, regardless of the order in which they are added. This is due to the commutative property of vector addition: The sum of all vectors remains constant. Consequently, the final position of the random walk is unaffected by the order in which the vectors are arranged.

[10] Something reminiscent of the sum over all possible histories in the path integral formulation of QM.

permutation of the same vector set does *not* change the histogram frequencies. Because the vector elements remain the same, the count within each histogram bin is also unchanged, regardless of their combinatorial arrangement. This frequency invariance indicates that the probability distribution of the vectors is also invariant. This is obvious, as they are always the same vectors. Emphasizing this (only seemingly) trivial point will be crucial next.

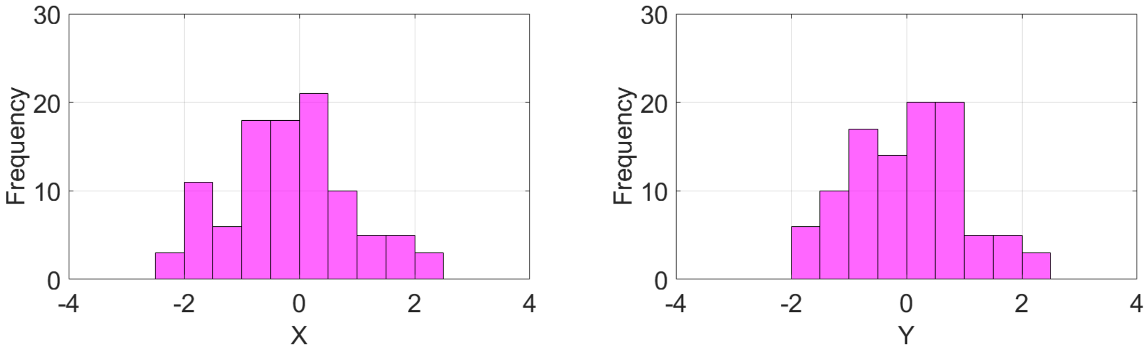

Fig. 4 Frequency of the X and Y coordinates of the vectors.

Thus, shifting the causal principle of a mental agent, whether spatial or non-spatial, from interactions based on physical forces to a conscious causal power that engages with potentialities—specifically, the temporal ordering of quantum microphenomenal events—constitutes a form of causality that selects and actualizes a path from a set of many possible histories. It is the same stochastic quantum principle underlying the scattering processes with many possible histories defined by the scattering amplitudes we saw in Section I.3. However, here, the actualization of the 'history' does not require conventional interactions, defined as a force exchange, to exercise a causal power. Instead, a volition that can permute the sequence of possible quantum events—specifically, one that chooses among quantum states limited only by the laws of quantum physics that determine the probability function—is sufficient for efficient causation. The interaction problem doesn't arise because this is a causal principle that doesn't need 'interactions' or 'transference' of 'substances' in the first place. It relies solely on a causal power to permute the time series of actualizations from a specified set of potentialities.

Most importantly, this 'combinatorial causality' does not alter the frequency of outcomes and, therefore, does not affect the wave function or its associated probability function. As a result, no laws of physics must be modified, and there are no issues with conservation principles.

There is a long tradition that used quantum mechanical effects to try to overcome the challenges of interactive dualism (e.g., (Bass, 1975), (Mattuck, 1982), (Stapp, 1993), (Burns, 2002), (Schwartz, 2005)). Theories suggesting potential quantum effects in neurons and other biological cells—such as wavefunction collapses in microtubules, ion channels, or other molecular complexes, as well as the influence of quantum uncertainty on the macroscopic behavior of large structures like brains—are not new.[11] The perspective presented here doesn't compete with such outlooks; rather, it could complement them.

This approach could also be interpreted from a panpsychist perspective, suggesting that all quantum processes in the universe might be fundamentally grounded in proto-mental choices, which I refer to as 'libertarian quantum panpsychism.' Nothing in the known laws of physics prevents us from entertaining such metaphysical speculation. Readers seeking more

[11] The most notable example of the former is Penrose and Hameroff's Orch OR theory (Hameroff and Penrose, 2014). For an interesting historical overview of the latter, see (Kožnjak, 2020a). For an assessment from the neuroscientific perspective, see (Jedlicka, 2017).

information about this approach can refer to (Masi, 2023a) and (Masi, 2024). However, one does not need to commit to this philosophical stance to appreciate the rationale behind this hypothesis.

III. Conclusion

This paper called for a reevaluation of traditional frameworks addressing the longstanding philosophical challenge known as the interaction problem. It proposed a perspective that aligns dualist views with contemporary scientific knowledge and explored semantic ambiguities, particularly through the lens of QFT.

The distinction between a ‘material’ and ‘immaterial’ mind is discouraged because of its misleading significance within a scientific context where massive versus massless particles are an entirely normal state of affairs and do not raise any conceptual difficulties typically associated with the problem of mental causation. More challenging is the terminological ambiguity concerning the distinction between what is meant by ‘physical’ versus ‘unphysical,’ which is necessary to avoid conceptual confusion in philosophical debates. The definitions based on classical physics, characterizing physical entities as those that occupy space and are governed by causal laws (suggesting that anything beyond these may be considered unphysical), are no longer adequate from the perspective of modern physics. The nature of causality and spacetime in quantum physics differs from classical notions.

Then, the concepts tied to quantum field dynamics in QFT, such as the coupling of fields depicted in Feynman diagrams as virtual particle exchanges and the notion of ‘contact’ or ‘collision’ between objects framed in terms of quantum processes, along with the nature of matter as a substance expressed through force fields, render classical notions of interaction and causality inadequate. Interactions are independent of the heterogeneity of quantum fields. Moreover, the same ontological status of substance and interaction that one finds in QFT makes them speak a very different language than that to which we were accustomed in debating interactionist ontologies. The vagueness of 'non-spatial' substances, once we consider quantum non-locality and entanglement in the context of Cartesian dualism, further alters the conceptual frame.

Taken together, these facts not only challenge traditional conceptions of space and substance but, if not acknowledged, also hinder a deeper understanding of the interaction problem. However, embracing the complexities of QM and the probabilistic nature of causality enables the outlining of a new understanding of mental causation—one that reconciles the dualist perspective with contemporary scientific insights. By exploring the concept of causality in a quantum theory without hidden variables and emphasizing how the order of events is crucial in determining a system's evolution, we could propose a 'combinatorial causality' concept. This could serve as a metaphysical model of mental causation based on an interaction-less form of causality, rooted in the probabilistic nature of QM, in line with physical laws, and not giving rise to issues involving violations of conservation principles.

Advancements in physics, particularly regarding new discoveries and the development of a future theory of quantum gravity, might reshape several points in this article. The primary aim here was to present the interaction problem from a more contemporary viewpoint. While concepts of mental causation might seem more complex, especially in light of current quantum theories that demand greater effort to understand, they also open up new and unexpected paths for exploring theories of mental causation. I hope that this exploration will inspire further research in this direction.

IV. References

Averill, E., Keating, B.F. (1981). “Does interactionism violate a law of classical physics?” Mind, **XC**: p. 102-107.

Bass, L. (1975). “A quantum mechanical mind-body interaction.” Foundations of Physics, **5**(1): p. 159-172.

Burns, J.E. (2002). “Quantum fluctuations and the action of the mind.” Noetic Journal, **3**(4): p. 312-17.

Carroll, S. (2021). Consciousness and the Laws of Physics. Journal of Consciousness Studies, Vol. 28, 9-10, pp. 16-31(16).

Cucu, A.; Pitts, J.B. (2019). “How Dualists Should (Not) Respond to the Objection from Energy Conservation.” Mind & Matter, 17(1), pp. 95-121.

Cucu, A. (2022). “Interacting Minds in the Physical World.” PhD thesis. doi: 10.13140/RG.2.2.23398.29767

Cohen, I., ed. (1978). “Isaac Newton’s Papers & Letters on Natural Philosophy and Related Documents.” Reprint 2014 ed. edition. Harvard University Press.

Crook, S.; Gillett, C. (2001). “Why Physics Alone Cannot Define the ‘Physical’: Materialism, Metaphysics, and the Formulation of Physicalism.” Canadian Journal of Philosophy, **31**(3):333-359.

Elpidorou, A. (2018). “Introduction: The Character of Physicalism.” Topoi **37**(435–455) Doi: https://doi.org/10.1007/s11245-017-9488-2

Hoffman, J.; Rosenkrantz, G.S. (1991). “Are Souls Unintelligible?” Philosophical Perspectives, Vol. 5, Philosophy of Religion, Ridgeview Publishing Company, pp. 183-212.

Hoffman, J.; Rosenkrantz, G.S. (2009) “Substance.” A Companion to Metaphysics, 2nd ed. Wiley-Blackwell, p. 83-94.

Jedlicka, P. (2017). “Revisiting the Quantum Brain Hypothesis: Toward Quantum (Neuro)biology?” Front. Mol. Neurosci., Sec. Molecular Signalling and Pathways, Vol. 10.

Judisch, N. (2007). “Why ‘non-mental’ won’t work: on Hempel’s dilemma and the characterization of the ‘physical’.” Philosophical Studies **140**(299–318). Doi:

Kastner, R.E.; Kauffman, S. (2018). “Taking Heisenberg’s potential seriously.” International Journal of Quantum Foundations 4:2, p. 158-172.

Kastner, R.E. (2022). “The Transactional Interpretation of Quantum Mechanics”, Cambridge.

Kim, J. (1993), “The Non-Reductivist’s Troubles with Mental Causation.” Mental Causation (Oxford, 1993; online edn, Oxford Academic, 31 Oct. 2023)

Kožnjak, B. (2020a). “The earliest missionaries of `quantum free will: A sociohistorical analysis.” In: Grgić, F., Pećnjak, D. (eds) Free Will & Action. Historical-Analytical Studies on Nature, Mind and Action, vol 6. Springer, Cham. Doi: https://doi.org/10.1007/978-3-319-99295-2_10

Kožnjak, B. (2020b) “Aristotle and Quantum Mechanics: Potentiality and Actuality, Spontaneous Events and Final Causes.” J. Gen. Philos. Sci. 51, 459–480. Doi: https://doi.org/10.1007/s10838-020-09500-y

Kuhlmann, M. (2010). “The Ultimate Constituents of the Material World: In Search of an Ontology for Fundamental Physics.” Berlin, Boston: De Gruyter, 2010.

Larmer, R. (1986), “Mind-body interaction and the conservation of energy.” International Philosophical Quarterly.

Libet, B., (1994). “A testable field theory of mind-brain interaction.” Journal of Consciousness Studies, **1**: p. 119-126.

Libet, B., (2006). “Reflections on the interaction of the mind and brain.” Progress in Neurobiology, **78**(3-5): p. 322-6.

Lindahl, B.I.; Arhem, P. (1994). “Mind as a force field: comments on a new interactionistic hypothesis.” Journal of Theoretical Biology. **171**(1): p. 111-22.

Masi, M. (2022). “Vitalism and cognition in a conscious universe.” Communicative & Integrative Biology, 15(1), 121–136.

Masi, M. (2023a). "Quantum Indeterminism, Free Will, and Self-Causation," Journal of Consciousness Studies, vol. 30, no. 5-6, pp. 32–56, 2023.

Masi, M. (2023b). "An evidence-based critical review of the mind-brain identity theory.” Front. Psychol., Sec. Consciousness Research, Vol. 14.

Masi, M. (2024). “Quantum Indeterminacy and Libertarian Panpsychism,” Mind & Matter, vol. 22, Nr. 1, pp. 31-50(20).

Mattuck, R. (1982). “A crude model of the mind-matter interaction using Bohm-Bub hidden variables.” Journal of the Society for Psychical Research, **51**(790): p. 238-245.

Montero, B., (2006). “What does the conservation of energy have to do with physicalism?” **60**(4): p. 383-96.

Ney, A. (2014). “Metaphysics: An Introduction.” New York, NY: Routledge.

Hameroff, S.; Penrose, R. (2014). “Consciousness in the universe: A review of the ‘Orch OR’ theory,” Physics of Life Reviews, vol. 11, no. 1, pp. 39-78.

Pitts, J.B. (2020). “Conservation Laws and the Philosophy of Mind: Opening the Black Box, Finding a Mirror.” Philosophia, 48:673–707.

Pitts, J.B. (2022). “General Relativity, Mental Causation, and Energy Conservation.” Erkenntnis **87**, p. 1931–1973.

Popper, K.; Eccles, J.C. (1977). “The Self and its Brain.” Springer International.

Robb, D.; Heil, J.; Gibb, S. (2023). "Mental Causation." The Stanford Encyclopedia of Philosophy (Spring 2023 Edition), Edward N. Zalta & Uri Nodelman (eds.), URL = **https://plato.stanford.edu/archives/spr2023/entries/mental-causation/**

Schrödinger E. (1951): “Nature and the Greeks and Science and Humanism.” p. 162, Cambridge University Press.

Seager, W. (2022). “Panpsychism and Energy Conservation.” Mind and Matter, 20(1): p. 17-34.

Simpson, W. (2024). “Cosmopsychism and the Laws of Physics: A Hylomorphic Perspective.” Journal of Consciousness Studies, **31**(9-10), pp. 132-157(26).

Shapiro, L. (2007). “The Correspondence between Princess Elisabeth of Bohemia and René Descartes.” University of Chicago Press; New ed.

Schwartz, J.M.; Stapp, H.P.; Beauregard, M. (2005). “Quantum physics in neuroscience and psychology: a neurophysical model of mind-brain interaction.” Philosophical Transactions Royal Society London, B Biol Sci, **360**(1458): p. 1309-27.

Stapp, H.P. (1993). “Mind, matter, and quantum mechanics.” New York: Springer-Verlag.

Stoljar, D. (2010). “Physicalism.” Routledge.

Taylor, E.F.; Wheeler, J.A. (1992). “Spacetime Physics.” Second Edition, p. 275, New York, W. H. Freeman and Co.

White, B. (2016). “Conservation Laws and Interactionist Dualism.” The Philosophical Quarterly, **67**(267): p. 387-405.

Wilson, D.L. (1999). “Mind-brain interaction and violation of physical laws.” Journal of Consciousness Studies, **6**(8-9): p. 185-200.