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Short Communication

Quantum aspects of the brain-mind relationship: A hypothesis with supporting evidence

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ABSTRACT

If all aspects of the mind-brain relationship were adequately explained by classical physics, then there would be no need to propose alternatives. But faced with possibly unresolvable puzzles like qualia and free will, other approaches are required. In alignment with a suggestion by Heisenberg in 1958, we propose a model whereby the world consists of two elements: Ontologically real *Possibles* that do not obey Aristotle's law of the excluded middle, and ontologically real *Actuals* that do. Based on this view, which bears resemblance to von Neumann's 1955 proposal (von Neumann, 1955), and more recently by Stapp and others (Stapp, 2007; Rosenblum and Kuttner, 2006), measurement that is registered by an observer's mind converts *Possibles* into *Actuals*. This quantum-oriented approach raises the intriguing prospect that some aspects of mind may be quantum, and that mind may play an active role in the physical world. A body of empirical evidence supports these possibilities, strengthening our proposal that the mind-brain relationship may be partially quantum.

1. Introduction

Of the three central mysteries in science, the Origin of the Universe, the Origin of Life, and the Origin of Consciousness, the last is the most challenging. As Fodor put it in 1992, "Nobody has the slightest idea how anything material could be conscious. Nobody even knows what it would be like to have the slightest idea about how anything could be conscious" (Fodor, 1992). Fodor's quip still holds true today. To be clear, in this article we do not propose what mind and consciousness *are*, but rather what they can *do*.

In 1996, Chalmers distinguished between the "easy" and "hard" problems of consciousness (Chalmers, 1996). The easy problem involves unraveling the physical correlates of consciousness, say the electrical action potentials propagating down neural axons, or the binding of some specific molecules in the post synaptic cleft joining the axon of one neuron to the dendrites of the next. Chalmers pointed out that no such knowledge would explain the mystery of being subjectively *aware* of the red color of a rose, the smell of coffee, the pinch of pain, or other aspects of "qualia." No reasonable account of physical happenings can account for qualia, thus that is the "hard" problem. For a more detailed discussion of these issues, see the article "What is Consciousness?" (Kauffman and Roli, 2022).

Associated with the mystery of qualia is the problem of *will*, meaning the act of intentionally choosing and doing. The specific problem is *free will*, such that one can be held accountable for one's actions. Broadly speaking, the topic of free will is either denied or not understood.

Here we explore alternative theories about the hard problems of qualia and free will. We believe there are testable answers, propose some of them here, and discuss supporting evidence that "mind" is at least partially quantum.

1.1. Theories of mind

1.1.1. Single substance theories

About 400 AD, St. Augustine of Hippo, a Neoplatonist, established much of the theological teaching of the early Catholic Church. He held that human consciousness was due to a direct connection to what he held to be the "Mind of God" (Tornau, 2020). In 1992, the Catholic Church celebrated the 150th anniversary of Darwin's "The Origin of Species," taking the enormous step of accepting Darwin's account of and reality of biological evolution. However, the Church retained St. Augustine's conception about the source of consciousness.

About 1660, Spinoza conceived of reality as being composed of a single "substance" with two aspects, mental and physical (Nadler,

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2018). Both were said to unfold deterministically in time, held in parallel temporal coordination by the Mind of God. Later, a version of Spinoza's view became known as Dual-Aspect Monism, which proposes that mind and matter emerge out of a single holistic "substance" (e.g., Jung's *unum mundus*). Dual-Aspect Monism is confronted with the issue of temporal coordination between mental and physical aspects of this neutral "substance" (Stubenberg, 2018).

The two principal alternatives to Dual-Aspect Monism are Idealism and Physicalism. Idealism proposes that all is mind, and that matter is in some sense "congealed mind." Bishop Berkeley proposed this view (Downing, 2021). Asked if a tree falling in a forest makes a sound when no one is there to hear the falling tree, Berkeley suggested that the sound existed because the falling tree was heard by God.

Physicalism, the dominant philosophy in science today, proposes that all is physical, and mind is somehow an expression of physical matter. It proposes that in sufficiently complex, classical physical neural networks, e.g., brains, that consciousness spontaneously emerges. This view underlies neuroscience's focus on the neural correlates of consciousness. However, it remains unclear how neural correlates resolve the hard problem of qualia and free will (as much as some have tried to provide answers) (Dennett, 1991). For example, a classical universal computer can, in principle, be made of connected water tumblers or tin cans. There seems to be no clear reason why a network of tin cans, in any configuration, could gain a sense of subjective self-awareness.

1.1.2. Dual substance theories

In 1640, René Descartes proposed two substances, *Res cogitans*, a mental substance, and *Res extensa*, extended substance (Descartes, 1999). This is the famous Cartesian substance dualism, mind stuff and matter stuff. When Descartes proposed his dualism, the Princess of Sweden asked him how mental stuff could possibly act causally on physical stuff. Descartes proposed the action occurred via the pineal gland in the brain.

This was a first step in the emergence of the mind body problem, still with us since Descartes: How does mind act causally on the brain? In 1687, after Descartes, Newton's three laws of motion, the law of universal gravity, and the use of integrated differential equations yielding entailed trajectories in phase space, founded deterministic classical physics (Newton, 2016). Classical physics is Descartes' *Res extensa*.

Given classical physics and its causal closure, if the mind-brain system is completely accounted for by classical physics, then the current physical state of the brain is entirely sufficient to determine the next state of the brain at the next moment. From that stance, there is nothing for mind to do, and worse*, there is no way for mind to "do it."* Thus, arises the familiar consequence: If mind-brain is adequately accommodated by classical physics, mind can at best be epiphenomenal and witness a world it cannot alter. As a result, due to the determinism of classical physics, there can be no free will. Legal reasoning about intentional acts is mute, and in general attempts to deal with this problem are called "compatibilism" (McKenna and Coates, 2021).

The proposal of an epiphenomenal mind poses overwhelming problems. Life on Earth is estimated to have started about 3.7 billion years ago. Presumably, mind evolved with life; we are its progeny. We have complex experiences, qualia, and the feeling of free will, but if our minds can only passively witness the world and not alter what happens, then it is difficult to imagine why mind exists at all. More deeply, if mind is epiphenomenal, then the proposal that mind evolved from simple to complex is incoherent without an evolutionary selective advantage (Nielsen and Day, 1999). More, Descartes proposed that only humans have consciousness (subjective awareness). We are driven to the desperate proposal that, unlike all other features of living things, our complex human mind arose utterly *de-novo* at some point in the evolution leading to humans, and nevertheless was maintained at metabolic cost over evolutionary time for no reason.

1.2. Quantum mechanics

The culprit at the root of this problem is the causal closure of classical physics. We ask mind to act *causally* on the brain and body, but in classical physics all of the causes are already determined. Because of this, no form of substance dualism within classical physics, *Res extensa*, can work. We are left either with Idealism, Physicalism, or Dual-Aspect Monism (and its cousin, Neutral Monism), which is what William James and Bertrand Russell concluded early in the 20th Century (Goodman, 2022; Russell, 1921).

We propose another possibility. Quantum Mechanics (QM), formulated in 1927, is currently the most accurate theory in physics, confirmed to at least 13 decimal places. QM has transformed our understanding of reality by replacing Newtonian determinism with indeterminism. It breaks the causal closure of classical physics, creating new possibilities for Mind to enter.

Until about two decades ago, the proposal that quantum effects could occur in the warm wet environment of living cells was dismissed due to assumptions about environmental decoherence, which occurs on a femtosecond time scale. Today, increasing evidence for quantum effects have been found in diverse areas of biology, from bird navigation (Pauls et al., 2013), to olfaction (Brookes, 2017), to photosynthesis (Ritz et al., 2002), and more recently to the human brain (Kerskens and Pérez, 2022). We base the rest of our discussion of the evidence for quantum mind in part on a novel interpretation of quantum mechanics.

1.3. Res potentia and Res extensa linked by measurement

In 1958, Heisenberg proposed that the quantum state concerns "potentia, ghost like, between an idea and a reality" (Heisenberg, 2007), similar to a concept proposed by Aristotle (Jaeger, 2017). We shall build upon this concept. Consider that the concept of a superposition, e.g., "the cat is simultaneously alive and dead," is a logical contradiction, so superpositions do not obey Aristotle's law of the excluded middle. On the other hand, the result of a quantum measurement, e.g., "the spot is here on the screen," does obey the law of the excluded middle. C. S. Pierce pointed out that *actuals* obey the law of the excluded middle, but *possibles* do not. For example, "The cat is simultaneously *possibly* alive and *possibly* dead" is not a contradiction. Thus, if quantum states are Possibles, then we can explain Schrodinger's cat. Superpositions are two or more Possibilities.

Following Heisenberg then, we propose a *non-substance dualism* (Robinson, 2020). In this view, the world consists of both ontologically real Possibles (i.e., *Res potentia*, that do not obey the law of the excluded middle) and ontologically real Actuals (*Res extensa*, that do). Mind converts these Possibles *acausally* into Actuals, where by the term *acausal* we specifically mean *without a physical cause* (Ball, 2022; Majorana Collaboration et al., 2022; Stapp, 2007). Such a "becoming" is not deductive. The "X is Possible" of *Res potentia* does not entail the "X is Actual" of *Res extensa*. Indeed, no deductive mechanism has been found since the foundations of QM, suggesting that such a mechanism may not exist.

Heisenberg's "*Res potentia* and *Res extensa* linked by measurement" interpretation explains five mysteries of quantum mechanics: 1) Why measurement of one of N entangled variables instantaneously alters the amplitudes of the remaining $N - 1$ variables; 2) Spatial non-locality; 3) Which-way information; 4) Null measurements; and 5) Why there are "no facts of the matter" between measurements (Kauffman, 2020; Manousakis, 2006).

The explanation for the five mysteries is as follows:

I. Consider that you and I are to meet at Joe's Café the day after tomorrow. If, late today, Joe's café closes permanently, the *possibility* that we could meet there tomorrow has *vanished.* The closing of Joe's café is a change in what is now Actual. This alteration in what is now Actual *acausally* alters what is next Possible.

II. If, with Heisenberg, we interpret the quantum state as an ontologically real Possible, and if the result of measurement is an ontologically real Actual, then measurement changes what is now Actual. In turn that changes what is next Possible.

III. The above two points now explain the five mysteries:

1) For N entangled variables, measurement of one instantaneously (acausally) alters the amplitudes of the remaining N – 1 entangled variables.
2) If potentia are outside of spacetime, or put another way, simultaneously everywhere in spacetime, then that explains non-locality.
3) In the double-slit experiment, measurement of which-way information either determines that the photon did or did not go through, say, the left slit. If the measurement result is "left slit," then the *possibility* that the photon went through the right slit vanishes. This is the result of gaining which-way information.
4) By contrast, if the photon *did not* go through the left slit, then that possibility vanishes and the only remaining possibility is that the photon went through the right slit. This is null measurement.
5) Because potentia are not facts, between measurements there are no facts of the matter.

No other current interpretation of QM explains these five mysteries with a single hypothesis. Thus, it is reasonable to take seriously the hypothesis of *Res potentia* converted to *Res extensa* by measurement (Kauffman, 2016; Kastner et al., 2018).

Note that *Res potentia* and *Res extensia* is not a substance dualism, so it does not inherit the Mind Body problem. This is the first new proposal that may account for the mind-body relationship since Descartes, Berkeley, and Spinoza. Indeed, we are no longer left with a choice of Dualism, Idealism, Materialism, or Dual-Aspect Monism. With respect to the latter, since Spinoza it has had the problem of accounting for the *coordination in time between mind and body*. For Spinoza, this was accomplished by God. We provide a different hypothesis: Mind *acausally* mediates Actualization of Potentia (Kauffman, 2020; Shimony), so temporal correlation arises automatically. Again, by *acausal* we mean not via physical causes (Ball, 2022). That is, we propose that a partially quantum mind-body system allows a mind to have acausal consequences for the brain. In this case, mind is not merely epiphenomenal, *and therefore mind can have evolved due to selective advantage* (Kauffman and Roli, 2022).

The hypothesis that "mind" acausally mediates Actualization of Potentia is a scientific hypothesis, subject to test. We discuss evidence supporting this prediction below (Kauffman, 2020; Radin et al., 2012, 2013, 2015a, 2016).

1.4. Experimental predictions of quantum mind

Spatial nonlocality in the form of quantum entanglement has been firmly established as an empirical fact (Aspect et al., 1982), as noted by the 2022 Nobel Prize in physics (Billings, 2022). There is also modest evidence for temporal nonlocality (Jaeger, 2017; Filk, 2013; Megidish et al., 2013), e.g., photons that never existed at the same time can be entangled (Kauffman, 2016). *If the mind-body system is partially quantum, then certain kinds of nonlocal subjective experiences should be viewed as physically plausible*. If such experiences are ultimately based on entanglement, and presumably entanglement in living systems is fleeting, then these experiences would likely be fragile and require large-scale experiments, or meta-analyses of many independent replications, to detect the effects under well-controlled conditions.

If these speculations have merit, then one could predict that two types of anomalous subjective experiences ought to be reported: The mind would have the capacity to extend beyond the brain, and the act of mentally observing a distant physical system would, to some small degree, influence the behavior of that system. Such effects may also result in experiences where minds interact with other minds, or where minds perceive hidden or distant objects. Such experiences have been recorded in every culture throughout history and at every educational level (Radin, 2018). They are even reported in surveys by a high proportion (over 90%) of contemporary scientists and engineers (Wahbeh et al., 2018).

Interpretation of these experiences as *real* has been ridiculed by critics because they assert that such phenomena must violate one or more physical laws (Carroll, 2008), or because claims of such experiences are due to mental deficits, ignorance of scientific principles, or fraud. Some of the latter assumptions may be valid in selected instances, but critical analysis finds that these assumptions are not universally applicable, and in some cases they are demonstrably incorrect (Radin, 2022). In addition, concerns about supposed violation of physical laws would be justified if the world only consisted of classical physics. But of course, that is not the case.

If these experiences could be confirmed in properly designed and executed experiments, and then successfully replicated and published in peer-reviewed journals, and if they were reframed as physically plausible, then the evidence should be taken more seriously because the implications go to the heart of quantum mechanics, the physical correlates of consciousness, and beyond (Rosenblum and Kuttner, 2006).

2. Evidence

Experiences that appear to transcend the everyday constraints of space and time, or suggest that mind can interact directly with matter, have been systematically studied since the late 1800s (Alvarado, 1983). Over more than a century, a host of rigorous experimental methods were developed to study such experiences, some of which have been adopted as standard techniques in conventional disciplines, including the use of statistical methods to evaluate data in human behavioral research, double-blind protocols to preclude investigator biases, and meta-analysis as a way to objectively assess replication (Watt, 2005).

Some of these experiments have been replicated dozens to hundreds of times in laboratories around the world. The results have been meta-analyzed to assess whether the reported effects are repeatable, to provide estimates of effect sizes, to study how variations in experimental quality influence effect sizes, and to estimate possible biases due to selective reporting.

A 2018 review of this evidence, appearing in *American Psychologist*, the flagship journal of the American Psychological Association, surveyed the results of over a thousand relevant experiments in 11 categories. The conclusion of the review was unambiguous:

> The evidence provides cumulative support for the reality of [nonlocal consciousness effects], which cannot be readily explained away by the quality of the studies, fraud, selective reporting, experimental or analytical incompetence, or other frequent criticisms. The evidence … is comparable to that for established phenomena in psychology and other disciplines (Cardeña, 2018)' p1.

Two years prior to that publication, the President of the American Statistical Association reached the same conclusion. She wrote:

> For many years I have worked with researchers doing very careful work [studying these anomalous experiences], including a year that I spent full-time working on a classified project for the United States government, to see if we could use these abilities for intelligence gathering during the Cold War … At the end of that project I wrote a report for Congress, stating what I still think is true. The data in support of [these] phenomena are quite strong statistically and would be widely accepted if it pertained to something more

> mundane. Yet, most scientists reject the possible reality of these abilities without ever looking at data! (Utts, 2016)[,p. 1379]

That last comment may seem like rhetorical hyperbole, but the reality is that some critics today continue to argue that "there is no good reason to consider the data" (Reber and Alcock, 2019)[,p.8]. That statement appeared in an article published in response to the aforementioned meta-analysis published in *American Psychologist*. Those authors argued that:

> If the physicalist-materialist framework of modern science is correct within the bounds of demonstrability and theoretical coherency—and everything that has been learned through science says that it is—the fact that [these] phenomena are so grossly inconsistent with that framework suggests that they are all but impossible and that the claims made by proponents cannot be true (Reber and Alcock, 2019)[, p2].

In other words, leading critics today assume that our present understanding of the physical world is sufficient to understand all possible aspects of the mind-brain relationship. That belief might have been consistent with known physics at the end of the 19th century, but not with physics of the 21st century. Critics also tend to sidestep the growing evidence and implication of quantum biological effects, as well as evidence suggesting that consciousness may not be an emergent property of the brain (Wahbeh et al., 2022).

Nevertheless, based on their convictions, critics ignore relevant evidence and insist that current theories trump the data. The history of science shows that this is a common strategy when confronted with observations that challenge the status quo, but it is also a poor bet given that scientific knowledge is constantly evolving, as reflected by college textbooks that require new editions every few years (Kuhn, 1962).

The world is quantum, and by virtue of its spatial and temporal nonlocality, experiences that reflect these effects may be viewed as not only plausible, but as *expected* to occur if the mind/brain relationship is also – even to a miniscule degree – quantum. The idea of "quantum consciousness" in warm, wet, noisy brains has become a legitimate topic of discussion (Sbitnev, 2016; Hameroff and Penrose, 2014), and the consequences of quantum effects on nonlocal properties of consciousness have been proposed, mostly by physicists, since the 1970s (Jahn and Dunne, 1986; Josephson and Pallikari-Viras, 1991; Mattuck, 1982; Chari, 1972; Walker, 1979; Squires, 1990).

What then is the empirical evidence in favor of quantum-like experiences? Here we briefly review three categories of relevant experiments, involving correlations in mental imagery in pairs of people who are strictly isolated from each other, perception through time, and mind-matter interactions.

2.1. Mental imagery correlations

2.1.1. Conscious impressions

Since the 1970s, the technique most frequently used to study nonlocal connections between minds isolated by distance or shielding is called the ganzfeld experiment, where *ganzfeld* is a German word meaning "whole field." The method involves exposing a "receiver" of information to a mild form of unpatterned sensory stimulation. The receiver relaxes in a comfortable, reclining chair, the experimenter tapes halved Ping-Pong balls over her eyes, and then asks her to wear headphones that play pink noise (Bem and Honorton, 1994). Then the experimenter directs a red light toward her face, and she is asked to keep her eyes open. Resting in this condition for a few minutes encourages the mind to slip into a dream-like hypnogogic state, which is thought to enhance the ability to pay attention to subtle mental impressions.

After relaxing in this reverie state, the receiver is asked to speak aloud anything that comes to mind over the next 20 min while a "sender," who is strictly isolated by shielding and distance, mentally sends her a target image. That image is a randomly selected photograph (or in some tests, a video clip) out of a randomly selected pool of 4 images (or videos), each target in the pool being as different from one another as possible. A typical ganzfeld experiment will have several dozen such target pools prepared in advance. None of the photos used in the experiment would be known to the sender or receiver, and no one who directly interacts with the participants is allowed to know the identity of the randomly selected target photo used in a given test session.

After the 20-min sending period, the receiver is taken out of the ganzfeld condition, shown four photographs, then asked which image best matches her impressions of what the sender was mentally "transmitting." By chance, assuming that mental correlations do not exist, she would select the correct target on average 1 in 4 times, for a 25% hit rate. If after repeated trials with many sender-receiver pairs the overall hit rate were sufficiently above chance expectation, and experimental controls were firmly in place to prevent information leakage or cheating, then that would provide evidence that the receiver's mental impressions correlated with those of the sender.

To prevent any form of conventional information from passing between sender and receiver, these studies follow strict security protocols established in consultation with stage magicians and illusionists, because of their familiarity with deceptive practices, to close all known loopholes (Bem and Honorton, 1994; Dalton et al., 1996; Utts, 1991).

From 1974 to 2018, 117 ganzfeld studies were published. Of those, experiments using target sets with 4 possible targets comprised a total of 3,885 test sessions, resulting in 1,188 hits, and thus corresponding to a 30.6% hit rate (Storm et al., 2010). With chance expectation at 25%, the excess hit rate was 8.1 sigma above chance expectation ($p = 5.6 \times 10^{-16}$). Analysis of these studies showed that similar effect sizes were reported by independent labs, that the results were not affected by variations in assessed experimental quality, and that selective reporting biases could not explain away the results. The Bayes Factors (BF) associated with the last 108 more recently published ganzfeld studies, which were designed to take into account all potential methodological "loopholes" claimed by skeptics, was 18.8 million in favor of distant mental correlations. Given that a BF greater than 100 is considered "decisive" evidence, this outcome exceeds the exceptional evidence said to be required of exceptional claims by four orders of magnitude (Jarosz and Wiley, 2014; Jeffreys, 1961). By comparison, in particle physics experimental outcomes resulting in 5 sigma are considered experimental "discoveries" (Lamb, 2012). An update to this meta-analysis, including all studies reported through 2020, confirmed the earlier report (Storm and Tressoldi, 2020).

The modest 5% advantage over chance expectation in the ganzfeld studies, most of which were conducted *without* selecting participants claiming special abilities, suggests that this phenomenon is widely distributed among the general population. However, in a subset of these studies participants were selected based on having had previous experiences of this kind, or because they maintained an active meditative practice (Vieten et al., 2018), or engaged in creative pursuits (Thalbourne, 2000), or strongly believed that these kinds of experiences were real (Storm and Tressoldi, 2017). The overall hit rate for the subset of such participants was a robust 40.1%, and still 6.2 sigma above chance expectation ($p = 2.8 \times 10^{-10}$) (Baptista and Derakhshani, 2014).

If some people have a natural predisposition for these abilities, possibly due to genetic differences, then such capacities might be subject to natural selection and may indeed have evolved. This in turn opens the door to heritability analyses. Confirmation of heritability would be powerful evidence for both the reality of these phenomena, and for a role that these aspects of mind may have had in its evolution. Preliminary evidence for heritability exists in surveys among families in Northern Scotland who claimed an ability dubbed "second sight" (Cohn, 1999), and also in a recent genomics study, where hints of differences in non-coding DNA were observed in individuals whose families claimed to have these exceptional mental abilities, as compared to matched controls who did not (Wahbeh et al., 2022).

Critics may argue that these experiments were conducted only by "believers," which may raise doubts about the credibility of the published results. In 2005, two professors of psychology who explicitly disavowed belief in any form of anomalous mental abilities replicated the ganzfeld experiment using the methods described above. In their published report, to their credit they reported that:

> After eight studies, we had an overall hit rate of 32% (which agrees with the positive meta-analyses) and, in fact, our hit rate was also statistically significant (Delgado-Romero and Howard, 2005)[, p298].

2.1.2. Electrocortical evidence

Another way that this mental correlation effect has been tested takes advantage of the neural correlates of consciousness. These experiments explored if electrocortical activity in the brains of pairs of people isolated by distance and/or shielding would show significant correlations when one member of the pair was exposed to audio tones, light flashes, or other stimuli known to generate event-related potentials in the brain. One of the earliest experiments of this type, involving sets of identical twins, was published with positive results in 1965 in *Science* (Duane and Behrendt, 1965). Another was reported in 1974, again with positive results, in *Nature* (Targ and Puthoff, 1974). Over a dozen other experiments have been reported using similar protocols, including studies with positive outcomes conducted using functional MRI (Karavasilis et al., 2018; Richards et al., 2005; Standish et al., 2003). Formal meta-analyses have not been attempted on this class of experiments because the broad range of methods used makes it difficult to uniformly compare them. But a case can be made that the preponderance of these neurophysiological studies are in conceptual agreement with the results of the ganzfeld experiments (Radin and Pierce, 2015).

2.1.3. Autonomic nervous system evidence

A third approach to investigating this phenomenon was based on the observation that both the ganzfeld and brain correlation experiments apparently involved the central nervous system, so perhaps similar effects might appear in the autonomic nervous system (ANS). Experiments examining the predicted correlations between isolated monozygotic twins, in parameters such as electrodermal activity and variations in heart rate, have reported positive correlations in two separate experiments (Jensen and Parker, 2012; Parker and Jensen, 2013). A larger class of ANS experiments has been tested within a paradigm based on the commonly reported "feeling of being stared at." The typical protocol in such studies isolates two people, where a "receiver" is monitored for changes in electrodermal or other ANS reactions as they relax quietly, while a distant "sender" periodically views their image over a live closed-circuit video channel. The sender is asked to mentally "contact" or intently stare at the receiver when the image appears, and then to withdraw their attention when the image disappears. The hypothesis is that under conditions where ordinary sensory clues are strictly excluded the receiver will unconsciously sense when they are being observed by the distant sender, and their nervous system will react accordingly.

A meta-analysis of these experiments retrieved 36 high-quality studies consisting of 1,015 individual sessions. The overall result was 3 sigma ($p = 0.001$) above chance expectation (Schmidt et al., 2004). A second meta-analysis of 15 additional studies using similar protocols, and involving 379 sessions, resulted in an overall 2 sigma ($p = 0.01$) outcome. Examination of the distribution of effect sizes in these studies revealed no selective reporting biases that might have favored a positive outcome, and the correlation between study quality and effect size was not significant. The author of these meta-analyses cautiously concluded that "the existence of some anomaly related to distant intentions cannot be ruled out" (Schmidt et al., 2004)[,p. 245].

2.2. Perception through time

Several classes of perception-through-time experiments have been reported. One such test involves conscious selection of one target from a limited set of randomly determined future targets. Another involves unconscious responses to future stimuli.

2.2.1. Forced-choice tasks

In the first case, the experimental design invites participants to guess which of a limited set of possible targets (like a set of colored lamps) would be randomly selected by a true random process (like radioactive decay latencies) in the future. The outcome of the experiment would be evaluated as the proportion of observed hits over many repeated trials, as compared to chance expectation. A meta-analysis of such forced-choice experiments conducted between 1935 and 1987 (the date of the reported meta-analysis) found 309 studies reported in 113 publications reported by 62 different principal investigators (Honorton and Ferrari, 1989). Over 50,000 participants contributed nearly two million trials in these studies. The result was a small positive effect but given the large sample size the effect was 11 sigma above chance ($p = 6.3 \times 10^{-25}$). The effect size remained stable over a half-century of replications while the experimental quality systematically improved, and an estimate of selective reporting biases was deemed incapable of reducing the overall results to null.

2.2.2. Physiological tasks

While the forced-choice tests provided intriguing evidence, the small effect size required very large datasets to yield significant results. This led researchers to explore more sensitive measures, including unconscious physiological responses. One of the more successful approaches did not require the participant to consciously guess the future event, but rather to unconsciously "feel" the future event. This protocol was based on a laboratory simulation of what is reported in real life as spontaneous gut feelings or hunches about unpredictable future events (often associated with highly positive or negative emotions) (Radin, 1997).

In this experiment, the participant's skin conductance, heart rate, pupil dilation, EEG, or other physiological measures are recorded before, during, and after exposure to a series of randomly selected stimuli (Mossbridge and Radin, 2018). The stimuli might be photographs with different degrees of emotionality and valence, or the presence or absence of light flashes, audio tones, or electrical shocks. The hypothesis is that a few seconds prior to exposure, the physiological measure would respond differently to the upcoming calm versus emotional or startling future events.

The first published meta-analysis of these studies retrieved 26 relevant publications from 1978 to 2010 (Mossbridge et al., 2012). The results showed a significant effect ranging from 5.3 sigma ($p < 5 \times 10^{-8}$) to 6.9 sigma ($p < 2 \times 10^{-12}$), depending on whether a random effects or fixed effects meta-analytical model was employed. Higher quality experiments resulted in larger effect sizes and greater levels of significance than lower quality studies, and selective reporting was deemed insufficient to explain the results.

A more recent update found 27 new or previously unretrieved experiments conducted from 2008 to 2018. Results were compared between peer and non-peer-reviewed publications, and in preregistered versus non-preregistered studies. The results showed that peer-reviewed studies were associated with an overall 7.6 sigma outcome ($p < 10^{-14}$), whereas the non-peer-reviewed studies were associated with $p < 0.02$. Fourteen preregistered tests resulted in a 3.3 sigma effect ($p < 4 \times 10^{-4}$), whereas 22 non-preregistered tests resulted in $p < 0.007$. There was no evidence of publication bias, the results of both frequentist and Bayesian analyses converged to similar significant results, and there were no significant differences between effect sizes reported in peer and non-peer reviewed experiments (Duggan and Tressoldi, 2018).

2.3. Mind-matter interactions

2.3.1. Random physical systems as targets of mental intention

In 1627, Sir Francis Bacon published *Sylva Sylvarum*, a book that advanced the methods and significance of empirical research (Bacon, 1639). At one point in the book, Bacon proposed that the "force of imagination," by which he meant intention or will, could be studied by focusing the mind on objects he described as having "the lightest and easiest motions," including the "casting of dice." That suggestion presaged by 300 years the use of tossed dice in experiments designed to test the effects of mental intention on the behavior of random physical systems.

Systematic scientific tests using dice began in 1935 (Rhine, 1943). A meta-analysis published in 1989 found 73 relevant publications, representing the efforts of 52 investigators from 1935 to 1987 (Radin and Ferrari, 1991). Over that half-century, some 2,500 people attempted to mentally influence 2.6 million dice-throws in 148 experiments, and 150, 000 dice-throws in 31 control studies where mental influence was not applied. The number of dice tossed in a single throw ranged from 1 to 96.

The overall effect size was small, but the overall results were 19 sigma over chance expectation ($p \approx 10^{-80}$). A subset of 59 studies that used so-called "perfect" dice, designed to ensure that each die face had the same probability, and where the experiments reported homogeneous effect sizes, resulted in a more modest 2.6 sigma result ($p = 0.005$). The results of control experiments were uniformly within chance expectation. Variations in design quality and the possibility of selective reporting could not explain away these results.

Because conducting dice experiments were labor-intensive, as electronic circuitry advanced more efficient approaches were explored. This development was pioneered by physicist Helmut Schmidt, who developed automated electronic random number generators (RNG), where the output consisted of sequences of truly random bits (0s and 1s) (Schmidt, 1970).

In the earliest RNGs, randomness was based on latencies between emissions of radioactive particles and data were recorded on paper tape. As technology evolved, RNGs were based on noise from electron tunneling in Zener diodes, and the resulting data were recorded digitally. From the beginning, RNGs were constructed to be impervious to all known environmental influences encountered in normal laboratory conditions (e.g., variations in temperature, electromagnetic fields, voltage source, etc.), and the outputs were further "whitened" by passing the random bits through logical filters (e.g., exclusive-OR gates). Devices used in these tests were required to pass industry standard randomness testing suites.

Schmidt reported highly significant effects in many of his experiments (Schmidt, 1987), encouraging other researchers to try to replicate his results, and still others to propose theoretical models based on the role of observation in quantum mechanics (Schmidt, 1970; Houtkooper, 2002). One of the more systematic and rigorous replications was performed over a period of 12 years at Princeton University's Engineering Anomalies Research laboratory (Jahn and Dunne, 1986). That study strongly confirmed the effects reported by Schmidt (Jahn et al., 2007). A later multi-lab consortium that attempted to replicate the effect failed to confirm their earlier results (Jahn et al., 2000), but other anomalies in the data were observed (Jahn et al., 2000).

The first meta-analysis of these studies, published in 1989, retrieved 152 publications describing 597 experimental and 235 control studies reported by 68 different principal investigators (Radin and Nelson, 1989). Any experiment using an RNG as the target of mind-matter interaction was included in that analysis. The results showed a 6.8 sigma effect ($p = 5.23 \times 10^{-12}$) in the experimental data, null results in the controls, no significant effects due to selective reporting, and no correlations with assessed experimental quality.

A second meta-analysis published in 2006 examined a subset of the relevant literature that only involved studies using very similar designs and protocols (Bosch et al., 2006). It included some 380 experimental and 137 control studies reported in 117 publications. The authors concluded that the results of 377 of the experimental studies produced a fixed-effect result 3.6 sigma above chance ($p = 0.0002$) and a random-effects model 4.1 sigma above chance ($p = 2.25 \times 10^{-5}$). Three studies were excluded because each contained over a billion random bits, and together those three studies amounted to over 210 times as much data as the other 377 studies combined. When just those three studies were considered, they resulted in a −4.03 sigma deviation from chance ($p = 5.6 \times 10^{-5}$, two-tailed). This outcome was opposite to the direction of the assigned intention, but it nevertheless confirmed the presence of an anomaly associated with mental influence of the probabilities of random bits.

Despite these findings, those authors concluded that the results may have been due to selective reporting biases. A reanalysis subsequently argued that that conclusion was flawed because the selective reporting model that the authors used could not account for the extreme heterogeneity of the experimental results (Radin et al., 2006). That counterargument was later confirmed by independent analysts (Varvoglis, Bancel).

2.3.2. *Mental influence of interference patterns in double-slit optical systems*

A more recent class of mind-matter interaction experiments has focused on von Neumann's proposal that the transition from quantum *Possibles* into classical *Actuals* involves a psychophysical component (von Neumann, 1955; Radin et al., 2012; Stapp, 2007). The experiment used optical double-slit interferometers because it is well accepted (if not well understood) that gaining which-path information about the path that photons take as they pass through the slits causes the wave-like interference pattern to shift into a particle-like diffraction pattern.

To perform such a test, individuals are asked to focus their attention toward or away from the double-slit apparatus to try to mentally gain information about the photons' path (which cannot be seen with the naked eye), or alternatively to intentionally alter their paths. To date, 30 experiments based on this design have been reported by five independent labs using conceptually similar protocols, continuous beam gas and diode lasers, single-photon designs, and various analytical approaches (Radin et al., 2012, 2013, 2015a, 2016; Ibison and Jeffers, 1998; Guerrer, 2019; Vujanac et al., 2019). Of these tests, 14 were reported as statistically significant at $p < 0.05$ (two-tail), where just one or two would be expected by chance. So far, the cumulative binomial probability of this success rate is associated with $p < 4 \times 10^{-11}$.

To date, commentaries about these studies have appeared in five publications. Two offered different theoretical interpretations of the data (Sassoli de Bianchi, 2013; Pradhan, 2015). One reanalyzed data from one of the published studies (Radin et al., 2013), and after a statistical correction that analysis confirmed the original results (Radin et al., 2015b). In another reanalysis, data were reanalyzed from a two-year online double-slit experiment (Radin et al., 2016; Tremblay, 2019). That analysis confirmed that the originally reported results were correct, but when each of the two years of data were considered separately (thus reducing statistical power) the results of only one year was found to be significant. In a follow-up article, the same author found that an outlier rejection method used in the original study had inflated the results, and when corrected neither of the two years of data were deemed significant (Tremblay, 2021). Fortunately, the original article also reported an analysis without rejecting outliers, and that result remained statistically significant. A later reanalysis of these same data that took into account mind-wandering, which can reduce or distort the effectiveness of focused attention, found strong statistical evidence that the double-slit component of the interference pattern exhibited larger shifts in variance when humans were engaged in the task, as compared to when a computer simulated human participants (Radin and Delorme, 2021).

A different critique claimed that in another double-slit experiment a false positive occurred in a control condition, raising doubts about other published studies using similar methods (Walleczek and von Stillfried, 2019). However, that argument was flawed because it failed to account for multiple statistical comparisons, which was required by the protocol used in that study (Radin et al., 2020).

As a relatively new line of research, caution is warranted in interpreting this class of experiments. But it is worth noting that the observed results to date are consistent with the more mature empirical database involving RNGs. If successfully confirmed by future replications, these studies would strengthen the suggestion that the mind does indeed play a role in the becoming of the universe. Our understanding of the world and our role in it would change.

3. Discussion

3.1. Responsible free will

The body of experiments discussed in the previous section could, for the first time since Newton, scientifically allow for a "responsible free will." For example, in the mind-matter interaction experiments, participants "try" to alter the probability of truly random events or to mentally influence the fringes in an optical interference pattern. "Try" is another word for "Will." In our normal lives, we believe that we convert intended Possibles to Actuals all the time by choosing and doing, where counterfactually we could have chosen and done otherwise.

The core question is this: Could such a free will be responsible? In QM, the outcome of measurement is ontologically indeterminate, breaking the causal closure of classical physics, but entirely random as given by the squared amplitudes of the wave function via the Born Rule. We may act with apparent freedom, but if we still randomly hit the little old lady on the head with a rock, if freedom is in fact an illusion, then we are not responsible for such a reprehensible act.

However, if the mind-matter interactions studies are valid, then a human can not only "try" to alter the outcome of a physical system by intentionally altering the probabilities of the outcomes of measurement, say by bending the Born rule, but their will can actually accomplish their desire. Thus, Mind trying and doing can alter the outcome of "actualization" to behave non-randomly. A responsible free will is not ruled out. Defendants can be held legally responsible in courts of law.

The proposal that mind mediates actualization of potentia, either via will or through nonlocal modes of observation, contains a difficulty: Before, e.g., human minds, measurements nevertheless occurred. How? One answer is provided in the article, "What is Consciousness?" (Kauffman and Roli, 2022), which presents a model that is consistent with the growing realization that consciousness is found throughout the animal world (Nieder, 2022).

A further answer is a form of panpsychism where interacting quantum variables measure one another. There are grounds to hold this view of QM. It is consistent with the Strong Free Will Theorem that says that electrons "freely decide" to become Up or Down upon measurement (Conway and Kochen, 2009). The now confirmed "dud bomb experiment" demonstrates that quantum variables can act on one another even in "interaction-free" experiments (Elitzur and Vaidman, 1993; Kwiat et al., Wolf).

3.2. The hard problem

Our proposal does not answer Chalmers' hard problem of qualia. But we do suggest that a "burst of consciousness" happens upon a quantum actualization. In this we parallel Hameroff and Penrose's proposal (Hameroff and Penrose, 2014), but we note that their position links an event of consciousness with collapse of a superposition of multiple potential spacetimes into one actual spacetime. They may be correct, but there is no obvious reason to link their version of quantum gravity with an event of consciousness. We would also note that consciousness plays no role in Hameroff and Penrose's spacetime collapse, so in their model consciousness is not an active agent; it is epiphenomenal. By contrast, our proposal that reality consists in Possibles and Actuals linked by measurement invites a natural place for Mind: it is the means by which quantum potentia are actualized. The empirical results of mind-matter interaction experiments support this suggestion.

Our proposal is similar to that of Chalmers and McQueen (in Gao, 2022). They propose that an incomplete Quantum Zeno Effect collapses the wave function. In their case they suppose a Cartesian Dualism. We do not. Moreover, Chalmers and McQueen hope for a currently unknown mechanism that would yield an incomplete Quantum Zeno Effect. Apropos, Kauffman and Patra have recently described such a mechanism as a consequence of the emergence of the classical world in a finite system of entangled variables (Kauffman and Patra, 2022). The concordance is encouraging.

4. Conclusion

If all aspects of the mind-body relationship were completely accounted for by purely classical physics, then quantum mind and the range of subjective experiences that might result from that basis, would be – as critics insist – impossible. This conclusion was taken for granted by many scientists until quantum biological effects were discovered. Today, with growing evidence for quantum effects in living systems, and in particular in the brain (Georgiev, 2021), it is increasingly plausible that some aspects of brain function operates in a quantum fashion, and as such it is time to take proposals for quantum mind and its consequences more seriously. Given continuing developments in quantum biology in the first decades of the 21st century, it may not be irresponsible to take the relevant empirical evidence discussed here as an indication that there are indeed spatial and temporal forms of non-local consciousness in living systems, as well as an active role for mind in the physical world.

Compared to research on particle physics being conducted at CERN, experiments required to test the concepts discussed here are inexpensive, and yet they carry implications at least as profound as any observed in physics. If further experiments continue to show repeatable, positive effects, and especially if these phenomena are shown to have a genetic component, then we will be more secure in their reality and be driven to ask about the possible survival value such phenomena have played in the long evolution of mind since the origins of life on Earth some 3.7 billion years ago.

Mind, in short, may have had – and still have – an active role in the evolution of the world.

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