QUANTUM AND HUMANITIES

Quantum discomfort: reflections on art and interdisciplinarity

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Golden time, quantum dimensions. Conceptualization: Luisa Quiroga

As a composer who has been engaging with quantum physicists for the past four years, I experience a sense of unease when I hear the term quantum art. Like many others prefixed with "quantum", the term has become increasingly popular in recent times. So ubiquitous has it become that even a frying pan I recently purchased bore a label proclaiming its use of "quantum technology". Unfortunately, the definition of quantum technology has been stretched beyond its scientific meaning, leading to an array of imprecise and sometimes misleading uses of the term. In the arts, where definitions are continually revised and reinvented, the word quantum is also subject to broad interpretation. Consequently, many artists may self-identify as quantum artists, and artworks may be presented as quantum art, ranging from tenuous connections of two seemingly disparate things (entanglement) to explorations of atomic inspired themes.

I feel fortunate to have held a position, first as an artist-in-residence and then as a post-doctoral researcher at ICFO (Institute for Photonic Sciences) in Barcelona, where every day more than 400 physicists pursue their respective physics research projects. The captivating world of quantum physics is a perpetual source of creative inspiration for me, and I am certain that I am not the only artist who finds inspiration in this field. However, the frequent exploitation of the word quantum in the arts industry troubles me, particularly since I have gained a better understanding of quantum physics research.

Quantum art

Many people associate the mention of "quantum art" with photography contests during science week, exhibitions at science museums, or trendy Instagram posts from emerging quantum-related industries. Alternatively, they may recall encounters with self-proclaimed "quantum believers" offering meditation, personal coaching, and energy healing with crystals and universe-themed artwork in the background. This misrepresentation of quantum physics is understandably frustrating for genuine researchers in the field.

It is worth noting that not all self-taught individuals lack knowledge and expertise. However, in various settings, such as airports or science exhibits, I have had encounters with individuals claiming to be self-taught quantum physicists. When I mention my work as a composer that collaborates with quantum physicists, some have responded, "Me too! I'm an artist that believes in quantum!" While there is nothing inherently wrong with self-taught knowledge, discussions can become unproductive when the basis of the "research" under discussion is Facebook posts and mystical websites. Such websites tend to use their owner's personal idea of quantum physics to feed their own spiritual belief system, and that of their community.

Still, I was extremely confused about the relationship and the hype of quantum physics in spiritual practices. When I saw the marketing hook, "Are you ready to go quantum?", on a website advertising the Quantum Life Coaching certification programme for USD 6,497, I finally understood the researchers' frustration at, not only the misused terms borrowed from quantum physics, but also the fact that their research is being misrepresented and used for commercial purposes. One quantum coaching academy charges USD 9,997 for its programme, while claiming that the "real value" of the programme is more than twice that amount.

> The captivating world of quantum physics is a perpetual source of creative inspiration. The combination of quantum and art seems to have created an ultimate ideal that resonates well with the general public

In today's climate, "creativity" is deemed an essential quality for entrepreneurs and business executives. Everyone is encouraged to be an artist, and even the development of new materials and faster computers using quantum technology seems to be primarily geared towards making money through artistic ventures. For instance, the ultimate goal of developing better smartphones is essentially to provide people with better tools to showcase their "art" on social media platforms. The combination of "quantum", which typically represents cutting-edge futuristic science (despite its 19th-century roots), and "art", which encompasses a wide range of aesthetic humanistic experiences, seems to have created an ultimate ideal that resonates well with the general public. As a result, "quantum art" is extensively used in monetization efforts as well as in scientific outreach activities.

Of course, there is often an inherent gap between the understanding of professional practitioners and that of the general public in any field. In the realm of film, excellent works such as Particle Fever (2013) and Interstellar (2014) accurately and genuinely employ quantum physics without excessive dramatization. Many other films and series use quantum physics concepts as flimsy excuses for highly improbable outcomes, such as the idea that everything and everyone can be connected through "entanglement", or that anything is possible because of "superposition". It is no surprise, then, that the general public often has misconceptions about quantum physics, given that many quantum world phenomena are exceedingly challenging to comprehend.

While I appreciate the works of many artists inspired by quantum physics, I must express my view that often, they frequently fail to effectively address this gap. For example, during an artist talk held in a crowded venue in Barcelona one evening, one such artist expressed their discomfort with the privileged and patronizing attitude displayed by academics towards individuals seeking knowledge outside traditional educational institutions. They emphasized that knowledge, such as knowledge of quantum physics, should not be limited to those privileged enough to study or engage in research at higher education institutions.

Although I generally agree with the sentiment expressed by the artist regarding the accessibility of knowledge, I could not help but notice the disappointment among the physicists in the audience as the artist presented their quantum-inspired artworks. In conversations I had with one scientist after the event, they explained that this disappointment stemmed from a perceived lack of respect for the depth of knowledge involved. Quantum mechanics, as a field of research, requires a solid foundation in advanced mathematics just to grasp the basics of its phenomena. Mathematics serves as the most effective tool currently available to explain quantum concepts, despite being a mere language of representation. Even with elaborate allegories, comprehending the true nature of quantum phenomena remains elusive for most individuals, myself included, who lack the mathematical background to be able to dive into the literature. Only in my third year of research at ICFO did I begin to appreciate the fascination experienced by quantum physicists. Beyond the mysterious effects of the quantum world I mentioned earlier, this fascination is produced by the inherent beauty of the mathematical equations that guide their exploration.

To be frank, this situation places me in an uneasy position. On the one hand, despite lacking a physics degree and apart from my own quantum art making, I still feel a certain responsibility as a sort of gatekeeper for quantum arts. Of course, there is no physical gate or enforcement body overseeing quantum art. I hold no position of great power or influence in academia or the art world that grants me the authority to prohibit anyone from practising quantum art. Nevertheless, I believe that my words and actions may carry weight simply because I am an artist who also works as a postdoctoral researcher at a physics institute.

Recently, I co-organized the Quantum Sounds Symposium in Barcelona, where I endeavoured to filter out any potential misinterpretations or misrepresentations by quantum art practitioners. Given that the symposium took place at ICFO, I felt a responsibility to ensure that the scientific aspect of the interdisciplinary art-making among the presenters was well founded and grounded. While I still have much to learn about quantum physics, I do appreciate the immense effort and meticulousness that researchers put into their work. In this context, I strongly feel that artists should respect the diligent work of scientists. It is important for us to acknowledge and honour the scientific rigour that underlies quantum physics, even if our own understanding may be limited.

However, on the flip side, I consistently encounter dismissal from scientists. It is disheartening to admit that the majority of scientists I speak to express genuine surprise that musicians like myself can hold doctorate degrees and that there are dedicated academic research journals and conferences focused on music and the arts. Regrettably, for many, the exploration of the intersection between art and science is often reduced to mere science communication or outreach efforts. While it is true that art has proven effective in science communication, particularly in leading scientific institutions like CERN, where art and artists can reach audiences that science institutions alone may struggle to engage with, we should not limit artists’ involvement in scientific research to the realm of communication.

> Quantic dissonance arises from the discrepancies in intuitive understanding between the classical and quantum worlds. Even quantum physicists themselves often struggle to reconcile these disparities

Nokia-Bell Labs’ historical EAT (Experiments in Arts and Technology) programme serves as an example. It aimed to foster collaborations between artists, scientists and engineers to push at the boundaries of technology and creativity. The programme sought to facilitate interdisciplinary projects that merged art, technology and scientific research, aiming to drive innovation and inspire new ideas. Unfortunately, the programme fell victim to today’s profit-oriented business mindset and the financial struggles faced by the institute. After a 54-year run, the EAT programme was shut down in 2021, one more casualty of the increasingly profit-driven environment.

Yet there is another perspective on the reservation within this interdisciplinary field. Many of my composer-researcher colleagues believe that merging quantum physics and music brings nothing truly new to the table, and is merely another form of algorithmic composition – a process that composers have been exploring since ancient times, including the practices of the ancient Greeks. They argue that the concept of using formal processes with minimal human intervention to create music has already been extensively studied and applied.

To summarize, the prevailing perception is that art-science projects, including those related to quantum art, are primarily seen as sources of entertainment rather than serious research endeavours. Among music specialists in particular, there is a belief that there is limited new territory to explore within this interdisciplinary realm. This widespread attitude contributes to my unease surrounding the term “quantum art”.

Quantum dissonance

That being said, I strongly suspect that “quantum dissonance” – as I mischievously call it, because physicists use the term differently – has a deeper origin. This dissonance arises from the discrepancies in intuitive understanding between the classical and quantum worlds. Even quantum physicists themselves often struggle to reconcile these disparities.

When I first began interacting with researchers, I was captivated by fascinating and mysterious quantum mechanics phenomena such as entanglement and wave-particle duality (which are among the most exotic). These phenomena fascinate us because they are not commonly experienced in our daily lives. Obviously, effects such as the live-dead cat paradox could never occur in the classical world we live in. Hence, many people struggle to intuitively grasp these phenomena, and I have even met individuals who claim not to “believe” in quantum physics. Even for those who do “believe” in quantum physics, it remains mind-boggling to imagine that the same atoms that make up our bodies behave so differently under certain conditions (such as at very low temperatures). It is clear that there are two distinct models of the world, where not only do things behave in completely different ways, but the concepts of universe and time would also be drastically different if we were to follow the laws of quantum mechanics.

I once approached a quantum physics researcher at the ICFO who was always patient and willing to explain things. I asked him how researchers deal with cognitive discrepancies of this kind. He smiled and responded, “The approach that many of us take is ‘shut up and calculate’”.

While this attitude may sound somewhat harsh, it emphasizes the importance of focusing on mathematical calculations and predictions based on physical theories rather than getting bogged down in philosophical or metaphysical debates about their meaning or interpretation. As the mathematical calculations of quantum mechanics became more precise, many physicists adopted a “shut up and calculate” attitude, arguing that the precise predictions produced by the theory were more important than any debates about its interpretation.

> The concepts of universe and time would be drastically different if we were to follow the laws of quantum mechanics

As I attempted to discuss this topic with other researchers, I was often met with frustration, changing the subject, or outright dismissal. There were exceptions, however; Dr James

Douglas, a theoretical physicist and co-author of *Quantum Physics for Hippies*, looked me straight in the eye and said, “The only consistent interpretation of quantum phenomena for me is the many-worlds interpretation, and that belief frames how I interpret everyday life”.

Many-worlds interpretation

The many-worlds interpretation (MWI) is a specific interpretation of quantum mechanics proposed by physicist Hugh Everett III in the 1950s. According to this interpretation, whenever a quantum measurement or observation is made, the universe branches into multiple copies, each corresponding to a different possible outcome of that measurement. In other words, every possible outcome of a quantum event actually occurs in a separate branch or “world”. In the many-worlds interpretation, these multiple branches or worlds coexist, but they are inaccessible to each other, meaning there is no interaction or communication between them. Each branch represents a different reality with its own set of events and outcomes, all existing in parallel.

The Many-worlds interpretation is often confused -or conflated by non-specialists- with a related but not identical concept known as the multiverse theory. While the MWI is a specific interpretation of quantum mechanics, the multiverse theory is a broader framework that encompasses various proposals for multiple universes beyond our own. The multiverse theory is a more expansive concept that suggests the existence of multiple universes or a collection of parallel universes beyond our own. These universes could differ in their physical laws, constants or initial conditions, potentially leading to different realities. The multiverse theory includes various specific proposals and hypotheses, such as the bubble multiverse, the brane multiverse, and the landscape multiverse.

In popular culture, these concepts have inspired numerous creators of science fiction, including Terry Pratchett and Stephen Baxter in their novel The Long Earth and Stephen King in his epic fantasy series The Dark Tower. The recent film Everything Everywhere All at Once achieved success by exploring the possibilities offered by these concepts. Literature, film and television have extensively explored these concepts, often presenting imaginative and thought-provoking scenarios.

Whether or not the concepts of multiverse and MWI are presented correctly in these works, while the multiverse theory and the MWI may seem far-fetched, these ideas have gained traction among physicists and cosmologists as a possible explanation for some of the mysteries of the universe, such as the fine tuning of physical constants and the apparent lack of symmetry in the cosmic microwave background. However, the existence of multiple universes remains a topic of active debate and investigation within the scientific community.

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But if Dr Douglas believes that many versions of him exist in parallel universes, surely his everyday experiences would be completely different from those of the majority of us, to say the least? Surely the knowledge of numerous other selves would make him feel uneasy? Surely it would influence the decisions he makes in his daily life? And what about death? With so many versions of himself, does death hold any significance for him? If he experiences unfavourable consequences, does the knowledge of a parallel universe in which he made different choices offer him solace? How does Dr Douglas view others who do not share his belief in the multiverse theory? Does he consider them less enlightened when he sees people struggling with difficult decisions?

Quantum phenomena through sound

For a while now, senior theoretical physicist at ICFO Dr Maciej Lewenstein and I have collaborated on interdisciplinary research projects that aim to convey various quantum phenomena in an intuitive manner through sound. Although sound itself is a classical phenomenon that can be heard by human ears, we find the connection between sounds and concepts such as space and ephemerality intriguing, particularly in relation to certain quantum physics phenomena. One area of particular interest to us is the possibility of merging quantum randomness with music composition. This common interest arises from Lewenstein’s extensive expertise in quantum randomness and my long-standing fascination with the use of imperfection and randomness in music composition.

The incorporation of randomness in music composition has been extensively explored by modern composers through methods such as chance operations, random number generators, and computer-assisted composition. However, the types of randomness employed have largely been apparent or deterministic in nature. Our current endeavour revolves around utilizing quantum randomness to manipulate the Fourier frequency spectrum of sound parameters, potentially uncovering patterns in timbral changes. Perfect quantum randomness would prevent discernible patterns, while classical randomness would eventually reveal some, or at least that is what we aim to determine.

Essentially, our project is an attempt to gain an intuitive understanding and come to terms with the quantum world, as physicists such as Dr Douglas presumably perceive things through their calculations and their knowledge. Dr Douglas and others who share his views (including David Deutsch, Sean Carroll and David Wallace) on the many-worlds interpretation seem to be in the minority among quantum physicists. Most physicists, knowingly or unknowingly, adhere to the “shut up and calculate” approach. This highlights the complexity of understanding the general concepts of quantum physics and the difficulties involved in reconciling our intuitive understanding of the quantum world. Whether or not it involves the MWI, my goal is to personally reconcile both worlds in a way that I can intuitively understand. While achieving this goal might seem challenging, I plan to continue exploring the use of sound as a tool in my endeavour. Music technologists and artists such as Eduardo Miranda and Spencer Topel have been actively researching the intersection of quantum physics and music. They delve into areas such as quantum computer music and quantum oscillators, among other intriguing avenues. These curious artist-researchers are just two of the many individuals out there exploring the interface between quantum physics and music.

Advocate for interdisciplinary research beyond economic impact

To those who question the economic impact of interdisciplinary fields like this, I often find myself delivering a speech similar to the one commonly given in defence of fundamental research in science. Though it may sound lofty, it is the most honest answer I can provide at present. In the documentary film Particle Fever, an economist in the audience posed a question to physicist David Kaplan regarding the financial benefits of conducting the expensive initial proton-proton collisions at the Large Hadron Collider in 2008 and the potential discoveries to be made. Kaplan proudly responded, “I have no idea”, and went on to say, “When radio waves were discovered, they weren’t called radio waves because there were no radios. They were initially discovered as a form of radiation. The basic science required for groundbreaking discoveries often needs to be pursued without solely focusing on economic gain. Instead, we must inquire about what we don’t know and where we can advance.”

The source of my discomfort in response to the term quantum art is perhaps primarily due to the financial implications it carries. Deep down, I yearn for all people to be captivated by its inherent sense of mystery, encompassing all the unsuccessful endeavours to merge two distinct fields and discovering the minute possibilities where they intersect, rather than focusing on obvious outcomes measured by fame, great discoveries, art awards and financial gain. In essence, the term appears to favour outcomes over process, placing disproportionate value on the end result and overshadowing the significance of the creative process itself.

It is my personal belief that both artistic creation and scientific research require investment in the process itself, even when this entails financial losses and lacks a direct contribution to a grander purpose. This conviction stems from recognizing the immense value inherent in the acts of research and creation when propelled by genuine curiosity and passion. Such endeavours transcend mere financial gain or institutional recognition. Nevertheless, the term quantum art somehow serves as a reminder that my romanticized view may not be universally shared, and this realization perhaps accounts for my quantum dissonance.

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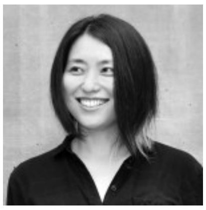

Reiko Yamada

Reiko Yamada is a composer and sound artist originally from Hiroshima, Japan. Yamada holds a D.Mus in music composition from McGill University, and is a recipient of numerous prestigious awards and fellowships. She was a Fellow at the Radcliffe Institute for Advanced Study of Harvard University, the artist-in-residence at IEM (Institut für Elektronische Musik und Akustik), the Innovator-in-Residence at Colorado College, and the S+T+ARTS resident artist. Her various projects have been commissioned and/or funded by New Music USA, the Canada Council for the Arts, IRCAM (the Institute for Research and Coordination in Acoustics/Music), CIRMMT (the Centre for Interdisciplinary Research in Music Media and Technology), the *Conseil des arts et des lettres du Québec*, Armitage Gone! Dance, the *Zentrum für Orgelforschung der Kunstuniversität* Graz, and the European Commission, among others. Her works have been presented at venues such as the Metropolitan Museum Breuer (New York), and Sónar Festival (Barcelona). She is currently a postdoctoral researcher at ICFO (Institute for Photonic Sciences) in Barcelona.