Research Essay

Quantum Theory & Consciousness

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Abstract

A recent research paper entitled "Generating mechanical and optomechanical entanglement via pulsed interaction and measurement" is paving the way towards demonstrating that even macroscopic harmonic oscillators can display this 'spooky' phenomenon in quantum mechanics of being 'entangled', that is to say information is passing between these harmonic oscillators faster than the speed of light. The neurons in the brain are in fact harmonic oscillators and it is argued that the 'binding problem' in cognitive science is solved if it turns out that all the neurons in the neural network are in fact entangled harmonic oscillators which means that information from different neurons or sets of neurons from diverse regions of the brain can integrate simultaneously to generate in us a unified or holistic consciousness. The philosophical implications of some of the 'weird' aspects of quantum mechanics are discussed.

Keywords: Niels Bohr, Copenhagen Interpretation, wave function collapse, entanglement, brainwaves.

The phenomenon of entanglement in quantum mechanics is well known even by the general public, and is poorly understood by non-experts and experts alike. Even Einstein was baffled by it and famously referred to it as 'spooky'. Basically quantum particles seem to defy our fundamental conceptions that we are living in a real physical world where there are 'causes' and 'effects' which occur after the lapse of a certain amount of time and in a defined space in the universe. Entangled particles defy the classical laws of physics in as much as they appear to act on each other instantaneously over distances that are clearly impossible in the real world. Originally it was thought to be only particles at the quantum level that displayed this peculiar characteristic which begs the question whether at the quantum level time and space actually exist at all. It has now been proved beyond doubt that many subatomic particles and indeed even atoms and larger molecules can display this property of entanglement and there is very active research as to just how big objects have to be before they cease to display this 'spooky action at a distance'.

How to entangle macroscopic objects using particles of light

A recent research paper has proposed a new way of creating entanglement between mechanical motion and an optical field, and also between two mechanical oscillators, using short pulses of light.[1] The authors say: "Making an entangled state of something bigger allows us to test

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quantum physics on a macroscopic scale and paves the way for the development of powerful new quantum technologies, such as sensing and quantum networking. In this work, we propose a new technique to create such quantum states by using quantum optomechanics. In our scheme, light bounces off two tiny mechanical oscillators causing them to move, creating an entangled state in their motion."[2]

According to the authors: "It is a very exciting time in quantum optomechanics at present, as early signatures of quantum motion of mechanical oscillators are now being observed. In this work, we theoretically proposed and analysed a powerful new approach to create entanglement between mechanical motion and an optical field, and also between two mechanical oscillators, using short pulses of light."[2]

This research is the first theoretical proposal for preparing and verifying mechanical and optomechanical entanglement in the emerging field of pulsed optomechanics. This highlights a route to observe quantum entanglement in a regime where it hasn't been seen before. More specifically, there are two main regimes in quantum optomechanics. One is the "resolved-sideband regime", where light circulates inside an optical cavity for a timescale that is long compared to the mechanical period. The other is the "unresolved-sideband regime", which allows for rapid pulsed interactions over a timescale much shorter than the mechanical period. Optomechanical entanglement has not yet been observed in this latter regime and this research makes key steps in this direction. The authors report that one of the most important results from their work is that in the pulsed regime creating such entanglement looks experimentally accessible, and is robust to effects that often hinder its observation. And most importantly further advances in this research will address very fundamental questions, such as "what are the limits of quantum theory?" To these ends, a key current goal of research is to create and observe entanglement on larger and larger mass scales.[2]

> Studying the various forms of optomechanical entanglement is an active current area of research and there have been several theoretical, and more recently experimental, studies exploring this avenue. While we do not aim to provide a thorough review here, we briefly describe and contrast some key studies of both optical–mechanical and mechanical–mechanical entanglement.
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> Focussing first on theoretical proposals, a notable early direction on optomechanical entanglement was to use photon–phonon transfer operations, where non-classical and entangled states of light are mapped onto the motion of mechanical oscillators via light–matter beamsplitter interactions.
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> Interactions of this type require operation in the resolved-sideband regime of optomechanics, which is realized if the mechanical frequency far exceeds the cavity decay rate. Following these proposals, detailed studies into the generation and detection of Gaussian optical–mechanical entanglement have been carried out, which focus on the linearized dynamics around the steady state. In the steady state, optomechanical systems are subject to certain stability conditions, which preclude parts of parameter space, particularly for optical drive on the blue

sideband. Long-pulsed optical drives operating in the resolved-sideband regime were suggested as a means to access this part of parameter space, and the effect of high thermal occupation, multiple interactions, pulse shaping, and different optical detunings have also been studied for such long optical pulses.

In addition to optical–mechanical entanglement, developing methods to establish entanglement between a pair of mechanical oscillators is also of key interest. In particular, the steady-state linearized dynamics of two mechanical oscillators interacting with the same entangling optical field have been studied to investigate Gaussian entanglement. Alternative experimental configurations have also been proposed, such as the suspension of two mechanical membranes within the same optical cavity, and the injection of squeezed light into both a double cavity system and a ring cavity design. The generation of mechanical entanglement via reservoir engineering of a single cavity mode by a multi-tone drive has also been suggested. Recently, a more comprehensive analysis of steady-state Gaussian entanglement has been carried out, which investigates optical–mechanical, mechanical–mechanical, and tripartite light-mechanics entanglement. Importantly, this analysis goes beyond the usual resolved-sideband regime and does not employ the rotating-wave or adiabatic approximations typically used in the literature.

Swapping optical–mechanical to mechanical entanglement by long-pulsed interactions, optical interferometry, and measurements provides another exciting route for generating entangled states of mechanical oscillators. In this setting, linear interactions and measurements on the optical field have been discussed as a way to generate Gaussian continuous-variable entanglement. Furthermore, complementary approaches that implement photon-counting measurements to generate and witness non-Gaussian mechanical entanglement have also been considered. Additionally, recent theoretical work, which proposes entanglement swapping between two optical and two mechanical modes offers a promising avenue to use mechanical entanglement to investigate spatially dependent decoherence in massive systems.

In recent years, field–mechanics and mechanics–mechanics entanglement experiments have been performed, demonstrating the interest in, and feasibility of, generating optomechanical entanglement. Notably, long-pulsed optomechanical interactions in the resolved-sideband regime have allowed entanglement between microwave fields and mechanical motion to be measured using optical-quadrature measurements. While in the optical domain, photon counting measurements have been used to witness non-classical optomechanical correlations between optical pulses and phonon modes in bulk diamond via off-resonant Raman scattering, and then similarly in a nanomechanical resonator operating in the resolved-sideband regime. Furthermore, mechanical entanglement has been established using an interferometric pump–probe scheme, first between two spatially-separated diamonds with photon-counting

> measurements on Stokes scattered photons, and then between mechanical resonators in the resolved-sideband regime of cavity optomechanics. Moreover, continuous driving of a non-interferometric configuration with two micromechanical drum oscillators has allowed for mechanical entanglement to be established mediated by microwave fields.[1]

Neurons are mechanical harmonic oscillators

A recent essay — "Solving the 'hard problem': Consciousness is an electronic phenomenon" argues that the action potentials (APs) of neurons occur as a result of electromagnetic processes.[3] Basically magnetite crystals also known as BMNPs (Biogenic Magnetic Nanoparticles) are ubiquitous in the brain and are superparamagnetic. This means that electric flux will magnetize them as will low frequency electromagnetic radiation (EMR) that acts upon them in exactly the same way as a magnetic field.[4] Magnetizing the BMNPs in turn generates magnetic flux which opens ion channels and enables current to flow thru the membrane of the neuron. The 'spikes' generated by action potentials are therefore mediated by this complementary relationship between electric flux and magnetic flux encapsulated in Maxwell's classical equations of electromagnetism. As these 'spikes' are actually an oscillating current along the axon they will also emit radio waves at the same frequency as the current. These radio waves are universally referred to as brainwaves which likewise can magnetize the BMNPs and initiate action potentials elsewhere in the neural network. Effectively this means that all the neurons in the neural network act as harmonic oscillators.

A new research paper has detected never-before-seen waveforms in the dendrites of the pyramidal neurons in the cortex of the brain.[5] The paper argues that these waveforms are mediated by neurotransmitters in the synaptic gaps which regulates the electric flux caused by the flow of calcium and sodium ions which actually modulates the amplitude and frequency of the 'spikes'. Up to now the spikes of action potentials were thought to be typical all-or-none flow of sodium ions as the action potential propagates along the axon and were not graded in any way but this new finding indicates that in the neurons of the cortex at least, the spikes are creating waveforms that vary in amplitude and frequency in such a way as to suggest that these oscillations are transmitting information about the neurons that have fired.[6]

It is submitted that this new research confirms the theory that consciousness is generated by electronics, that the brain is an electronic device and that the brains of all living creatures are connected electronic devices. In particular it indicates that the 'firing' of specific neurons will emit brainwaves of a unique frequency that will act as a signal to other parts of the neural network. Essentially the firing of specific neurons that have been programmed for individual functions acts as a transmitter of information via brainwaves to other sections of the neural network that have likewise been programmed – 'hard-wired' - to perform supplementary processing of this signal. Essentially neurons in other sections of the brain are 'hard wired' to act as an antenna for this unique signal.

The new research above indicates that the firing of neurons is mediated by neurotransmitters at the synaptic connections in a very complex way, and it is actually the firing of the neuron itself, or a specific set of neurons, which is directly generating a signal involved in processing output. From cognitive science it is quite clear that specific sets of neurons in specific parts of the brain are engaged in performing specific functions. And the overriding question in cognitive science is how the information from these diverse firings of neurons in spatially distant parts of the brain, even from different hemispheres, can somehow simultaneously coalesce into a unified output for multiple terminals i.e. the coordination of all functions of the body and its actions in the environment at once.

It is evident that the neurons are 'hard wired' to play a coordinated role in the generation of all bodily and mental operations, and there are plenty of instances where damage to the neurons in one part of the brain will cause defects in the performance of a function, but will not necessarily extinguish it, which indicates that neurons in other undamaged sections of the brain engaged in generating that function are still operating, and it is only the final coordinated output that is in some way impaired. Also there is evidence that if a part of the brain that performs a specific function is damaged at a very early age, then neurons in another section of the brain will be 'hard wired' to perform that function. At the risk of mixing metaphors, there is evidence of considerable plasticity in the 'hard wiring' of these neurons. This indicates that the 'hard wiring' of the neurons to perform their allotted functions is in the nature of a 'programming' of the brain. But that's where the analogy to conventional computers or Turing machines ends. There are no programs written in binary code, or any other numerical symbols, that are executed by electric current running thru logic gates, which will result in the neural network generating a specific output, globally coordinated or otherwise. When the neurons themselves receive a certain signal they will fire in a very specific way, which will transmit a very specific signal via brainwaves. That is their sole function: to fire when they receive a precise signal.

Recent advances in 'mind reading' technology has established that brainwaves communicate information.[7] Brainwaves are ELF (extremely low frequency) radio waves that travel at the speed of light. New research has revealed a novel waveform in the firing of neurons in the cerebral cortex which indicates that the 'spikes' of the electric flux in the action potentials are in some way mediated or controlled so that the waveform has a precise amplitude and frequency. In other words the waveform carries information about the precise neuron or set of neurons that fired. That information is communicated instantaneously to the entire neural network via brainwaves.

It is submitted that this solves the 'binding problem' in cognitive science. How functions achieved by different parts of the brain somehow combine their output into a single conscious percept. Not only does the problem of binding occur across components of a single modality, for example the shape and color components of the visual modality, but also the problem exists for multiple modalities: how is it that a single conscious experience contains information from vision, hearing, touch, smell, and taste, all at the same time? And sensory input is all seamlessly and instantaneously merged with our body schema and motor modalities, and our thought and language modalities. The problem is that there are too many multimodal areas. There are places in the temporal lobes which receive input from all modalities (the superior temporal sulcus), and places in the prefrontal lobes which also receive input from all modalities. One candidate for the neural substrate of binding is a type of resonation or oscillation which spans all of the bound areas. The binding problem is a problem about how the different parts of a conscious state are realized in such a way that they are parts of the same state.[8] The explanation is that the neurons are entangled harmonic oscillators.

Philosophical implications of entanglement

According to Richard Feynman, one of the leading contributors to the theory "I think I can safely say that nobody understands quantum mechanics." In this article it is argued that the neurons in the brain act as harmonic oscillators that are entangled by the brainwaves that they are transmitting and receiving. Brainwaves are ELF (Extremely Low Frequency) radio waves at the very bottom of the EMR (Electromagnetic Radiation) spectrum. They travel at the speed of light and they have extremely low energy.

Although this appears to be a perfectly straight forward explanation for how the brain works we find that it is really in the nature of a 'non-explanation' because we are attempting to explain brain processes with a mathematical theory that 'nobody understands'. Obviously we can see a brain with the naked eye so the brain is a macroscopic object, but that is not a working brain. That is a brain that has been taken out of someone's skull and is no longer functional. Once we start enquiring into how individual neurons work in a living brain we find that we are immediately thrust into the deepest enigma of all about quantum mechanics theory – the question of the observer and the measuring instrument. All of brain science involves reports of an observer who has obtained results from measuring equipment. In other words that brain has what's known as a 'wave function' that collapsed at the point when the measurement was taken. The only 'information' the brain scientist has gleaned from that measurement is that the object under observation, a neuron for example, was in a certain state at the precise moment of the measurement.

Nobody knows what the 'collapse of the wave function' means. For a start it is not a real physical wave, but exists only as mathematical theory as a probability amplitude which then has to be 'squared' to obtain the actual 'probability' that a certain 'result' will be obtained. All I can do in this article is give my own interpretation of what the collapse of the wave function means and why and when it occurs, and most importantly why it requires an act of observation from a scientist. Quantum mechanics is essentially about observing the operations of microscopic objects that cannot actually be observed through the senses. So instead of actually 'seeing' the object the observing scientist sees a piece of equipment that displays a certain measurement or result. That is the irreversible point when the wave function collapses – when the observing scientist becomes 'conscious' of the result of the measurement. What was only a probability wave has become real because it has produced a 'result' on the cortex of the observing scientist. In other words the object that was measured is completely irrelevant, all that is 'real' is the result that has now irreversibly appeared on the cortex and in the consciousness of the observing scientist. There is now only knowledge of that object that was measured, that is to say 'information'. What is in the 'consciousness' of the observing scientist is critical for all quantum mechanics theory.

Once we understand that quantum theory deals with the probability of a certain result appearing in the consciousness of the observing scientist we can pass over two major enigmas relative to this discussion relatively quickly – 'wave-particle' duality and 'entanglement'. Essentially EMR (including brainwaves) is normally considered to be a wave but if you pass it thru two slits and rig up a measuring apparatus to detect which slit it went thru a result will appear in the consciousness of the observing scientist that a particle went thru one slit or the other. But if there is no measuring apparatus and no result recorded in the consciousness of the observing scientist then a wave seems to pass thru both slits simultaneously. So depending on what inquiry the experimenter is making and what methods are used information will be generated in the consciousness of the experimenter that EMR (including brainwaves) is either a particle or a wave. This says nothing about what it actually is; there is no objective reality, only what the experimenter 'knows' subjectively.

The same considerations apply for the entanglement enigma. Two entangled particles share the one wave function. When Alice takes a measurement on one of the particles and a result (say spin up) appears in her consciousness then this collapses the wave function so it may be taken as a given that the other particle will be spin down. The information has been generated in the consciousness of an observing scientist and the state of the pair of particles is determined no matter how far apart they may be. It is simply not relevant to inquire why this should be so, and it is especially not relevant to relate this back to macroscopic conceptions of time and space. The wave function collapsed at the moment the information appeared in the consciousness of Alice and that is all we are permitted to know about the matter.

We now come to this notion that neurons are harmonic oscillators. Classically we think of a harmonic oscillator as a spring with a mass at one end which stretches the spring for a certain distance. If you pull the mass down and let it go the spring will oscillate up and down about a mean position. That oscillation can be represented mathematically by a sine or cosine wave that has a frequency that can be calculated by a standard equation in classical physics. Likewise EMR can be represented by a sine or cosine wave with a certain frequency. This concept of an harmonic oscillator has been adapted in quantum mechanics to describe objects at the atomic or molecular level.

In quantum mechanics the energy for a harmonic oscillator is given by the equation $\hbar\omega/2$ where $\hbar$ (h-bar) is Planck's constant and ω is the angular frequency. This is the ground state energy for the harmonic oscillator. Without getting too technical for the harmonic oscillator there is then a positive and a negative operator that acts on the wave function to increase and decrease the energy. And here is where the word quantum in quantum mechanics becomes most significant. The energy of the harmonic oscillator is increased by a quantized amount of $\hbar\omega$. We have already seen that brainwaves are ELF radio waves that is to say their energy or frequency is at the absolute bottom of the EMR spectrum which means that the discreet energy packets or quanta by which the neuron oscillates will be infinitesimally small but they will be able to transmit information throughout an entangled network of harmonic oscillators nonetheless. The oscillations give off brainwaves that represent discreet energy packets.

Conclusion

In previous articles I have argued that the 'binding problem' in cognitive science can only be solved on the assumption that different neurons or sets of neurons in disparate and widely separated regions in the brain are able to communicate with each other at the speed of light via brainwaves in order to generate on the cortex a unified or holistic consciousness. This paper takes that assumption one step further and argues that in fact all the neurons in the neural network are entangled harmonic oscillators emitting discreet packets of energy that enables information to merge simultaneously from diverse regions of brain to produce a holistic consciousness. Neural processes are not even limited to the speed of light. Because the harmonic oscillators are entangled the integration of information is instantaneous.

Received July 4, 2020; Accepted July 26, 2020

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