Review of: "The Brain as a Filter: Introducing a Quantum Ground into Integrated Information Theory"

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Potential competing interests: No potential competing interests to declare.

The paper proposes that a concept referred to as “quantum ground” could be applied to concepts from Integrated Information Theory to provide a filter or tuner from a more fundamental source of consciousness that would explain phenomenal consciousness and is related to Russellian monism.

Paper Strengths

The paper is well-written and well-organized. It is based on a solid understanding of the literature discussed in the article and provides supporting citations.

Paper Weaknesses

Section II is less of an explanation of IIT than a criticism of IIT. There is almost as much discussion of Chalmer’s ideas as of IIT.

Section III is more of a discussion of monism than what is meant by the term “quantum ground.” Quantum ground is not a well-known or defined term, and it is difficult to elucidate exactly what it is from the paper. The paper references 2 works as relating to the concept of quantum ground – Bohm and Hilley and Williams. Bohm and Hilley does not appear to use the term “quantum ground,” although it does discuss the more commonly understood concept of the ground state of a local quantum field. Williams discusses the quantum ground concept of Ismael and Schaffer and states that “their notion of a quantum ground appears to require something non-structural (not captured within the quantum formalism) that influences the system of entangled quantum states as a whole.” Ismael and Schaffer do not use the term quantum ground but refer to something called common ground, which might mean the same thing based on how it is used. Thus, it seems that the term “quantum ground” is not really associated with quantum mechanics but rather panpsychism. As such, it is unclear how the concept of quantum ground relates to any specific quantum mechanical behavior of neurons.

While there is a brief introduction to the idea of consciousness being related to entanglement, (Simon 2019) only proposes that entanglement should be further investigated (“I have proposed to seriously explore the possibility that quantum entanglement might have something to do with subjective experience.”). There is a better explanation in (Schaffer 2010) of entanglement, but the concepts of decoherence and decorrelation are not discussed. Decoherence severely limits the extent to which a wave function for one fundamental particle can functionally interact with the wave function of another fundamental particle. These interactions weaken as the number of interacting fundamental particles increases. Put another way, neuron function does not generally require consideration of quantum mechanics. In that

regard, the function that would be provided by the quantum ground is not identified. For example, the paper states, “I suggest the results are also consistent with an alternative interpretation: that focused attention by the experiment’s participants influences the system’s wave function as a whole (altering the Born probabilities) and thus leads to a more concentrated diffraction pattern.” This would only make sense if there were some quantum mechanical properties of the neurons that were capable of influencing and being influenced by neuron function.

The only source relied on by the author as evidence of any such quantum mechanical property is Orch-OR, which has been thoroughly researched but which has failed to produce any evidence of how 1) entanglement is created as a function of neuron activity, and 2) how focused attention by a person could influence the wave functions of entangled microtubules. It is also noted that even if large-scale coherence and entanglement of selected electrons in microtubules is eventually demonstrated and is shown to be influenced by and to influence neuron function, that would still not be a universal quantum ground because it would necessarily require that the entangled electrons are functionally interacting in a way that separates them from the rest of their environment. Instead, it would only be the quantum ground of the entangled electrons and would therefore seem to be unrelated to Russellian monism.

Specific Recommendations

1) Provide separate discussions of IIT and the criticisms of IIT by Chalmers and others.

2) Explicitly address and define important concepts of the paper, such as quantum ground, psi, Q-space, and anything else that someone who has not read all of the cited references might not be familiar with. The explanation of quantum ground should identify whether quantum ground is a physical concept that is associated with the quantum mechanical behavior of fundamental particles, or if it is a metaphysical concept – something “non-structural (not captured within the quantum formalism) that influences the system of entangled quantum states as a whole.” Are the quantum ground, psi, and Q-space dimensionless, or are there physical properties associated with them? Are they defined by variables, and if so, what are those variables? Is there a mathematical formula that describes the relationship between quantum ground, psi, and Q-space? A causal relationship between them needs to be shown or at least proposed if there is any filtering occurring because a filter discriminates between different types of matter or energy and blocks some while allowing others. For example, chemical reactions occur in liquids under earth ambient conditions due to gravity, but gravity is not involved in the reaction. Trying to describe chemical reactions using gravity as a filter instead of using the chemical properties of compounds would fail, but saying that gravity provides a force that brings reactants into contact with each other to allow them to react would be scientifically defensible.

3) Quantum effects in the brain are quantum biology. At the first Gordon Research Conference on Quantum Biology this year, Prof. Johnjoe McFadden noted that there is a “whacky factor” for some quantum biology ideas that can only be addressed with the scientific method – 1) hypothesis, 2) experiment, 3) apply results to the hypothesis, and 4) revise the hypothesis and repeat. Orch-OR and other quantum consciousness ideas have not been successful with the application of the scientific method in demonstrating that those mechanisms are capable of influencing and being influenced by neuron function, and there is a great deal of criticism of quantum consciousness ideas amongst physicists, neuroscientists, and mathematical consciousness scientists.

My own work in this area on catecholaminergic neuron electron transport (CNET) might be of interest to the author, as it provides something like a quantum ground along the lines of what Orch-OR was proposed for in the paper, but there is actual evidence of its existence, and it is consistent with the scientific method, thus avoiding the whacky factor. For example, it has been experimentally demonstrated that neural tissue can support widespread electron tunneling and that ferritin structures in neurons could result in strongly correlated electrons. Both of those observed physical phenomena could influence neuron function as a result of those quantum mechanical effects:

- Evidence of widespread electron tunneling in catecholaminergic neurons has been obtained; see (Rourk, Christopher J. "Indication of quantum mechanical electron transport in human substantia nigra tissue from conductive atomic force microscopy analysis." Biosystems 179 (2019): 30-38). That physical property was predicted by (Rourk, Christopher John. "Ferritin and neuromelanin “quantum dot” array structures in dopamine neurons of the substantia nigra pars compacta and norepinephrine neurons of the locus coeruleus." Biosystems 171 (2018): 48-58), which demonstrates the predictive power of the CNET hypothesis.

- Evidence of the ability of ferritin structures to conduct electrons over distances as great as 80 microns and to route electrons has been obtained; see (Rourk, Christopher, et al. "Indication of Strongly Correlated Electron Transport and Mott Insulator in Disordered Multilayer Ferritin Structures (DMFS)." Materials 14.16 (2021): 4527). This was also predicted by (Rourk 2018).

- The presence of such ferritin structures in macrophages and glial cells, as well as indications of electron tunneling associated with ferritin in a number of different biological systems, has been obtained from numerous sources; see (Perez, Ismael Diez, et al. "Electron tunneling in ferritin and associated biosystems." IEEE Transactions on Molecular, Biological and Multi-Scale Communications (2023). This was also predicted by (Rourk 2018).

- The existence of neural functions predicted by (Rourk 2018) was subsequently obtained by Prof. Pascal Kaeser of Harvard Medical School; see (Comment on Albantakis et al. Computing the Integrated Information of a Quantum Mechanism. Entropy 2023, 25, 449).

- The CNET mechanism has been applied to Integrated Information Theory (Rourk, Chris. "Application of the Catecholaminergic Neuron Electron Transport (CNET) Physical Substrate for Consciousness and Action Selection to Integrated Information Theory." Entropy 24.1 (2022): 91).

As explained in (Rourk 2022), strongly correlated wave functions of electrons in catecholaminergic neurons could relate in some manner to the creation of phenomenal consciousness (although that has not yet been done, and CNET is not a quantum consciousness idea). CNET is a quantum biological mechanism that is capable of influencing and being influenced by neuron function. Strong correlations of electrons in quantum wells like ferritin provide some protection of such quantum mechanical effects against decorrelation and decoherence. The corpus of strongly correlated electrons in groups of catecholaminergic neurons might satisfy what the author refers to as the quantum ground (albeit not in accordance with Russellian monism or any other panpsychist idea), and strong correlation of electrons is similar in some

regards to entanglement but can involve large populations of electrons, whereas entanglement usually refers to only two particles. CNET is also applicable to IIT, as well as to neural correlates of consciousness as discussed in (Rourk 2023). To date, there is no published criticism of CNET, and I note that my coauthors on (Perez et al. 2023) are solid-state researchers who peer-reviewed (Rourk et al. 2021). Several of them were initially skeptical of the results presented in (Rourk et al. 2021), but I was able to respond to their questions and address their concerns. In other words, I have been able to convince solid-state scientists that the quantum biological function of electron tunneling associated with ferritin appears to be involved in biological processes and systems, although further work is needed to determine whether there is direct evidence of the existence of CNET.

Conclusion

I think the paper could be improved by addressing the new evidence of CNET, which has not been considered by most consciousness researchers and thus falls outside the body of knowledge of quantum biological processes that occur in the brain, and which might be involved with phenomenological consciousness. In addition, strongly correlated electrons in neural tissue (for which evidence exists) could provide a quantum mechanical function that appears to be similar to what the quantum ground is supposed to be, in a local fashion, and thus is not dependent on hypothetical quantum entanglement and quantum consciousness ideas that have been heavily criticized and for which no evidence has yet been obtained.

I hope this feedback is helpful.