Review of: "Growing Confidence and Remaining Uncertainty About Animal Consciousness"

Christopher Rourk

Potential competing interests: No potential competing interests to declare. The only thing that might be identified as a "competing interest" is the noted disagreement between the reviewer's research and the author's conclusions, but that seems to be the purpose of peer review.

Review of Growing Confidence and Remaining Uncertainty About Animal Consciousness

The paper presents a review of the neuroscience literature that addresses phenomenological consciousness and identifies five areas of broad consensus. It also concludes that there are three “major mysteries” that remain about it: (1) the neurological correlates of consciousness, (2) the apparent gap between phenomenology and mechanism, and (3) the agent that monitors the brain activity admitted into consciousness.

Paper strengths

The paper provides a thorough review of the neuroscience literature and reaches what appears to be a valid conclusion that there are a number of areas of consensus. It is also correct that classical neuroscience cannot explain phenomenological consciousness. It is very well written and informative, and if the major problem discussed below is corrected, it will receive a “5-star” review.

Paper weaknesses

The paper states that “Most neuroscientists agree with the argument that consciousness arises from a physical substrate in a manner that will be uncovered in time, when newer data and insights conveyed through a more suitable vocabulary will clarify the link between mechanism and experience (P.S. Churchland, 1982; P.S. Churchland and Sejnowski, 1988; P.M. Churchland, 2013). We are not there yet though.” However, the work I have been doing has provided evidence and insight into the physics of that physical substrate that appears to be an important part of the link between mechanism and experience. Because the paper completely ignores that evidence, I have to give it a “1-star” rating. The author might not agree with some or all of my work, but at a minimum, any objective observations about that physical mechanism should be discussed if the paper is to meaningfully address and support the conclusion that there are “major mysteries.”

I will provide a brief overview of that evidence for the benefit of the author. In 2015, I read “Consciousness and the Brain: Deciphering How the Brain Codes Our Thoughts” by Stanislas Dehaene and reached the same conclusion as the author does in this paper - classical neuroscience cannot answer the question of why there is phenomenological consciousness. I also read Life on the Edge: The Coming of Age of Quantum Biology by Johnjoe McFadden and Jim Al-Khalili, which provides an excellent introduction to the new field of quantum biology, a field of research that many neuroscientists I have spoken with are unfamiliar with. Dehaene discusses some of the “quantum consciousness” ideas in his book, and I

generally agree with his assessments, including that they fail to provide an explanation for phenomenological consciousness. However, I also noted that none of them was discussed as quantum biological mechanisms by McFadden and Al-Khalili, and given the inability of classical neuroscience to explain phenomenological consciousness, it seemed that the new field of quantum biology might be worth investigating as it could relate to neuroscience.

I decided to investigate whether there are pigment-protein structures in the brain that are similar to the pigment-protein structures that support excitonic electron transport in photosynthesis. While I am not a neuroscientist, I do have a solid background in mesoscopic devices and electron physics (expertise that many neuroscientists probably do not have), and I was able to identify that ferritin and neuromelanin in catecholaminergic neurons appeared to have the right distribution and concentration to form structures that could transfer energy between the soma of those neurons. The function associated with this hypothesized neural signaling mechanism in those neurons (the substantia nigra pars compacta (SNc), the locus coeruleus (LC), and the ventral tegmental area, among others) is action selection, which the author notes at a number of points in his paper is integral with many of the aspects of consciousness for which there is agreement, such as:

- “consciousness is acknowledged as and often taken to be synonymous with current experience.”

- “Humans report and other animals behave as though they are attending to or aware of one thing at a time. This does not preclude the fact that awareness of peripheral or unrelated sensory perceptions is present, but that the organism’s attention is focused on one particular subject or event at a given instant.”

- “All the individual sensations or fragments of memory appear as an integrated and meaningful whole rather than a fragmented target of attention.”

- “All motile organisms show goal-directed behavior, and the role of consciousness in carrying it out has frequently been noted.”

- “Intentional movement is the way an organism interacts volitionally with its environment, and a consciousness of spatial orientation and extent is central to this ability.”

- “It also produced animals who handle their dealings with the world in a way that includes a tacit sense of self.”

- “Global accessibility and broadcast: the capacity to link and integrate information from perception, memory, and evaluative systems and broadcast the output back to input and executive systems that lead to relevant actions.”

- “Value attribution: the capacity to alter and update the rewarding or punishing values of actions and sensory stimuli.”

When the SNc and LC are destroyed by Parkinson’s Disease, death results, and as they are destroyed, there is progressive loss of motive and cognitive function. In addition, the neural mechanism associated with the selection of specific actions is still unknown. As such, there appeared to be a very clear connection between a signaling mechanism in those nuclei associated with action selection and consciousness. I published my first paper on the hypothesis in 2018, after receiving encouragement from a neuroscientist who performs research on catecholaminergic neurons (1).

I then commissioned Dr. Sara Ostrowski at EAG Labs in Silicon Valley to perform conductive atomic force microscopy tests on fixed human SNc tissue, which provided compelling evidence of predicted ferritin and neuromelanin structures that are capable of supporting widespread electron tunneling in that tissue. The results of those tests were also published (2). This is unusual evidence that has never before been observed, and nobody has refuted it. A number of researchers have cited it. The 2018 hypothesis was shown to have predictive power.

I then commissioned Prof. Cai Shen to test for the predicted long-distance electron transport through disordered ferritin arrays and for the predicted switching function that could be performed by those disordered ferritin arrays. Those tests provided compelling evidence of those predicted physical phenomena that was also published (3). This is also unusual evidence that has never before been observed, and nobody has refuted it. At least one researcher has independently confirmed it. The predictive power of the 2018 hypothesis was further demonstrated.

I subsequently published explanations of how the hypothesized catecholaminergic neuron electron transport (CNET) hypothesis relates to Integrated Information Theory (4, 5). I am in the process of publishing an updated explanation of the CNET hypothesis (6) as it relates to action selection as part of the cortico-striatal processing loop and other neural processing loops. I have also published a paper with a number of the leading researchers in the field of electron tunneling in proteins that describes how electron tunneling associated with ferritin appears to be involved in biological processes in mitochondria, the retina, the cochlea, macrophages, as part of ROS homeostasis, as part of magnetosensation, and other biological processes (7), and is not just limited to the brain. It appears to be present in nearly every living cell. As such, a large number of unusual and unexpected phenomena that were predicted by the CNET hypothesis have been observed, and it should be given serious consideration by neuroscientists and should be further investigated if such investigation is deemed worthwhile after serious consideration.

This information is provided in hopes that the author will consider this evidence of a mechanism that directly relates to and in some instances refutes the three “major mysteries” conclusion that is made by the author:

(1) the neurological correlates of consciousness – independent tests by Prof. Pascal Kaeser at Harvard Medical School have confirmed another unusual and unexpected prediction made by the CNET hypothesis, namely, that afferent cortical signals provided to striatal dendrites mediate action selection by stimulating the axons of SNc dopamine neurons to generate action potentials and cause the release of dopamine (see, e.g. (8, 9)). Stimulation of axons to create action potentials is very unusual – it’s essentially the opposite of how most neurons function, but it was predicted in 2018. Those afferent signals can be integrated by the CNET mechanism, which would explain how neural signals from widespread sensory and cognitive processing neural systems are tied together, namely, as part of the action selection mechanism (that the author acknowledges is an important part of consciousness). The CNET mechanism can thus integrate the observed NCCs as part of phenomenological consciousness.

(2) The apparent gap between phenomenology and mechanism – the CNET mechanism can help to explain that gap, but a better understanding of the CNET mechanism will be needed to fully explain it. It involves strongly correlated electrons, which are largely understood as a solid-state mechanism. I am the first person to provide evidence that it is also a

biological mechanism.

(3) The agent that monitors the brain activity admitted into consciousness – CNET indicates that this “agent” is a physical component of the unusual neural signaling mechanism in catecholaminergic neurons, and that brain activity is “admitted into consciousness” when associated afferent signals to the CNET mechanism reach a level that influences the physical behavior of that mechanism for the purposes of selecting whether to act or not to act. Not acting is an important part of that mechanism, as the wrong action can have fatal consequences, which is why consciousness persists continuously and not just when acting. Choosing the right food to eat, whether it is safe to go to the water to drink, and other choices required for deciding whether and when to act involve many aspects of qualia and would need to be practiced by any evolutionarily successful animal. See also (10) and related works, which are consistent with CNET and Kaeser’s work. In that regard, the basal ganglia has been conserved over 500 million years of evolution, and catecholaminergic neurons predate the basal ganglia, such as in C. elegans.

While many neuroscientists have been dismissive of my work and have failed to give it any substantive consideration (in fact, most do not even respond to polite enquiries, and when I have taken the time to follow up, I have been abused and treated rudely and unprofessionally by some of them), a number of neuroscientists and other scientists have reviewed it in detail and are supportive of it. However, as I am the only person that I am aware of who is working on this subject, I have the moral and ethical obligation to try to raise awareness of it with people who might be able to appreciate it, even if it means being ignored or dismissed out of hand most of the time. As shown by the IEEE paper, there is compelling evidence that electron tunneling associated with ferritin could be a factor in many biological processes and that understanding it may be necessary to treat diseases and disorders. As far as the paper goes, it would be of much greater import if it addressed these recent discoveries; otherwise, it is just rehashing information that has been mostly known since Dehaene published his book in 2015, a point which is generally acknowledged by the author (“Rather, it focuses on those aspects of consciousness about which there is a growing body of agreement in principle, if not in detail.”)

(1) 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.

(2) 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.

(3) Rourk, Christopher, et al. "Indication of Strongly Correlated Electron Transport and Mott Insulator in Disordered Multilayer Ferritin Structures (DMFS)." Materials 14.16 (2021): 4527.

(4) 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.

(5) https://www.mdpi.com/1099-4300/25/10/1436

(6) Rourk, Christopher. "Catecholaminergic Neuron Electron Transport (CNET): A Neural Signaling Mechanism." Qeios (2023).

(7) Perez, Ismael Diez, et al. "Electron tunneling in ferritin and associated biosystems." IEEE Transactions on Molecular, Biological and Multi-Scale Communications (2023).

(8) Liu, Changliang, Pragya Goel, and Pascal S. Kaeser. "Spatial and temporal scales of dopamine transmission." Nature Reviews Neuroscience 22.6 (2021): 345-358.

(9) Liu, Changliang, et al. "An action potential initiation mechanism in distal axons for the control of dopamine release." Science 375.6587 (2022): 1378-1385.

(10) Gurney, Kevin, Tony J. Prescott, and Peter Redgrave. "A computational model of action selection in the basal ganglia. I. A new functional anatomy." Biological cybernetics 84 (2001): 401-410)