Study Rules Out Fröhlich Condensates in Quantum Consciousness Model

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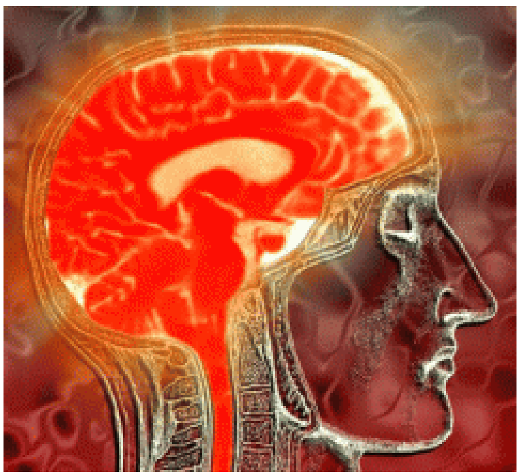

Researchers have found that the formation of coherent Fröhlich condensates requires high temperatures, making them incompatible with biological systems, and thus an unlikely component in the Penrose-Hamerhoff model of quantum consciousness.

(PhysOrg.com) -- Scientists don't fully understand how consciousness works, and, so far, no classical theories can explain consciousness in the brain. In light of this lack of understanding, some researchers suggest that quantum mechanics may play a significant role in the workings of the mind and the brain. Quantum consciousness theories have always been controversial, and now a recent study has undercut one more component of these proposals.

One quantum mind theory, proposed by physicist Roger Penrose and anesthesiologist Stuart Hamerhoff, is called "orchestrated objective reduction" (Orch OR). The theory suggests that microtubules, which are structural components inside cells, might function as cellular quantum computing elements. Inside the microtubules, coherence among quantum superpositions is maintained until the wave function collapses. Normally, a wave function collapses due to a measurement (i.e., interaction of the system and its environment), but here the collapse is postulated not to occur until the quantum superpositions become physically separated within spacetime geometry, called "objective reduction." When an area of quantum coherence collapses, an instant of consciousness occurs.

The physical cause of the coherent activity within the microtubules, as Penrose and Hamerhoff suggest, could be Fröhlich condensates. Proposed by physicist Herbert Fröhlich in 1968, Fröhlich condensates are similar to Bose-Einstein condensates in that both are systems with the unique collective property of macroscopic quantum coherence. In Fröhlich condensation, several vibrating oscillators can achieve a highly ordered condensed state, vibrating in resonance. Specifically, nearly all the vibrations occur in-phase at the Fröhlich condensate's lowest frequency.

However, Fröhlich condensates have never been unambiguously observed in experiments, despite intense research during the past 40 years. In a recent study in *PNAS*, researchers from The University of Sydney and The University of Queensland in Australia have investigated the basic properties of Fröhlich condensates in an attempt to determine the most likely methods to experimentally observe them. The researchers showed that extremely high energies and temperatures are required to form coherent Fröhlich condensates and hence they cannot exist in biological systems, as proposed by the Orch OR theory. Still, Fröhlich condensates could exist outside a biological environment, such as in terahertz radiation, which could have medical applications, and in microwave reactors used in “green” chemistry applications.

“The Penrose-Hamerhoff model is very good in that it provides a comprehensive proposal involving physics and biology, but this falls short in the area of the chemistry - the precise nature of the atomic motions involved in forming the basic quantum qubit,” lead author Jeffrey Reimers, a chemistry professor at The University of Sydney, told *PhysOrg.com*. “Our original intention was to take their proposal and run full simulations of the protein motion and hence provide a significantly enhanced and better justified model that would form the core of subsequent research.”

Instead, the researchers found that the Penrose-Hamerhoff model runs into problems due to the nature of Fröhlich condensation. In their study, the researchers show that, unlike Bose-Einstein condensation, Fröhlich condensation is a classical process that does not guarantee coherent motion. Fröhlich condensates are classified into three types (weak, strong, and coherent), with each type arising in different circumstances. In weak and strong condensates, the vibrations are incoherent but can still have profound observable effects on various systems by redistributing energy. In coherent condensates (the kind used in the Orch OR model), all the vibrational energy is in a single quantum state.

In calculations and simulations, the researchers showed that coherent Fröhlich condensates are very fragile and the coherence lasts a very short time - shorter than a single vibrational period. This finding agrees with the criticism of Orch OR that quantum coherence should decohere too quickly for it to have a significant impact on cognitive function. Also, the scientists showed that the formation of coherent Fröhlich condensates requires high energy and extremely high temperatures - up to 100 million Kelvin, which is not possible in any biological environment.

"Strictly, we show that Fröhlich condensation cannot cause quantum consciousness, so the challenge is then to find a way of implementing Orch OR in which coherence is guaranteed by some other process so that Fröhlich condensation is no longer required," Reimers said.

However, as the researchers elaborate in an upcoming paper, the involvement of a process other than Fröhlich condensation appears unlikely. As Reimers explained, coherence is known to exist in many analogous chemical and biological systems, including masers and photosynthesis, the latter of which is one of the most optimized quantum systems in biology. However, the coherence lifetime for these systems is only a few picoseconds, while Orch OR requires coherence on a timescale that is at least six orders of magnitude longer.

Nevertheless, weak and strong Fröhlich condensates may have realistic applications, though not in theories of quantum consciousness. The researchers found that weak condensates could have significant effects on proteins, and could possibly help explain enzyme actions in terms of excitation of vibrational modes, as Fröhlich originally proposed.

The researchers also suggested methods to observe the three types of condensates. In the past, researchers have attempted to observe coherent Fröhlich condensates by channeling a large amount of mechanical energy into a specific vibrational mode of a system. The current study shows that no amount of mechanical energy can produce a coherent Fröhlich condensate. Instead, the most likely ways to produce coherent condensates is by exposing systems to terahertz radiation or using microwave reactors.

Observing strong and weak Fröhlich condensates may be easier than observing coherent condensates, the researchers showed. For instance, mechanical energy sources might be able to produce strong condensates, and the interaction of radiation with biological systems could produce weak condensates.

More information: Jeffrey R. Reimers; Laura K. McKemmish; Ross H. McKenzie; Alan E. Mark; and Noel S. Hush. “Weak, strong, and coherent regimes of Fröhlich condensation and their applications to terahertz medicine and quantum consciousness.” *PNAS*. To be published.