Neuroscience presents a naturalized theory of consciousness

A new theory says that when ions interact with a neural membrane, that physical process creates a hologram — a detailed internal model of the world around us.

DENVER, CO, UNITED STATES, June 29, 2026 /EINPresswire.com/ -- A new theoretical paper published today proposes a naturalized framework for understanding human consciousness, contending that perceptual content emerges from probabilistic computation in the brain.

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> *Izi Stoll*

In a special issue in “Frontiers in Human Neuroscience,” philosopher Asger Kirkeby-Hinrup and neuroscientist Izi Stoll introduce a new approach to tackling one of the most enduring problems in science today: how neural activity in the brain gives rise to perceptual experience [1].

The paper presents consciousness not as an unknowable mystery, but as a measurable and physically grounded phenomenon. The authors compare their approach to the way scientists have uncovered natural processes for other biological phenomena.

“The study of consciousness has to move beyond identifying correlations with neural activity and toward explaining the biophysical mechanisms underlying consciousness,” says Dr. Stoll. “We have made an effort to do that.”

The new theoretical framework proposed in the paper builds on decades of neuroscience research showing that cortical neurons behave differently than simpler neural systems.

Neurons in the spine, for example, function much like transistors in a computer chip. They are either in an “on-state” or an “off-state”, firing or not firing. A sensory stimulus will cause these neurons to fire, triggering a spinal reflex. Neurons in the cerebral cortex, by contrast, do not automatically fire when they receive a signal. Instead, they exist in a ‘cortical up-state’, balancing excitatory and inhibitory inputs, and allowing random electrical noise to affect the likelihood of firing an action potential. These neurons have some probability of switching from off-state to on-state, based on many different inputs and random electrical noise.

The paper proposes that these noisy computational processes are not incidental, but central to conscious perception itself.

Essentially, this new theory suggests that our brains do physical work to extract a signal from the noise. In doing so, we find meaning as we parse data from our surrounding environment.

The theory is built on Stoll's mathematical models showing how ions move stochastically across the neural membrane and trigger an action potential, leading to the synchronous activation of neurons across the brain [2-4]. By carefully applying the principles of computational physics to neurophysiology, she shows how cortical neural networks uniquely process information.

"The critical difference with this approach is that we are talking about information as a physical part of our world, alongside matter and energy," explains Dr. Stoll. "This is not just an abstract computational quantity, or a distribution of possible system states. It's an actual thermodynamic quantity, a distribution of states for each ion in relation to each neuronal membrane. So this is a visceral process of encoding sensory data and representing that sensory data. We are continuously generating and compressing information to encode a "prediction" about the world."

According to the study, these ion interactions with the neuronal membrane not only physically encode information arriving through the senses, but also generate a holographic reconstruction of that sensory information as part of the brain's normal computational activity. The proposed "holographic solution" suggests that perceptual experience may arise through probabilistic interactions between ions and neuronal membranes in the cerebral cortex.

Dr. Karl Friston, Professor of Neuroscience at University College London, was not involved in the study. He comments: "This work presents a fresh model of information generation and compression — with implicit minimization of variational free energy. For neuroscientists, it offers a promising mechanism linking stochastic ion flux and probabilistic signaling at the neuronal level with representative content at the network level. For theoreticians, it has tantalizing connections between quantum information theoretic formulations and holographic encoding processes. These are welcome contributions to the field."

Notably, the theory addresses several longstanding mysteries in neuroscience, including the brain's remarkable energy efficiency, the ability of neurons to spontaneously rewire themselves to encode meaningful new information, the non-material-seeming nature of conscious experience, and why perceptual richness seems to be affected by temperature.

This neuroscientifically-grounded framework also generates concrete, testable predictions involving neural membrane properties, ion movement, and thermodynamic limitations, as well as the relationship between probabilistic neuronal computation and perceptual experience.

Dr. Kirkeby-Hinrup emphasizes: "This theory of consciousness offers a fully naturalized account that not only explains what subjective perceptual experience could be, in physical terms, but it is also amenable to empirical testing. This raises the bar for consciousness studies."

This work was conducted by researchers at Lund University and the Western Institute for Advanced Study. The Western Institute for Advanced Study is a Colorado-based non-profit research organization devoted to addressing historically-intractable problems in mathematics, physics, and the biological sciences, fostering a highly interdisciplinary and open atmosphere to promote intellectual progress. The full article published today is available at Frontiers in Human Neuroscience: https://www.frontiersin.org/journals/human-neuroscience/articles/10.3389/fnhum.2026.1816314/full

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