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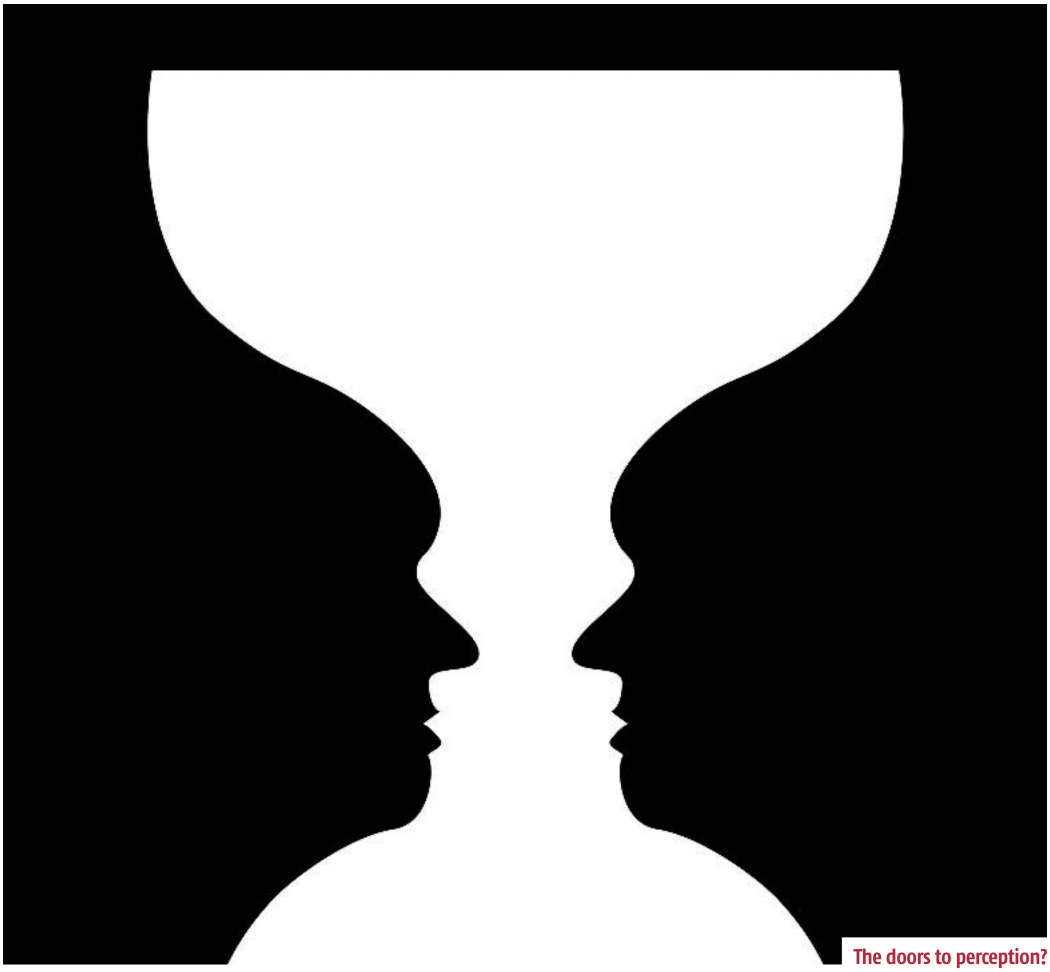

The doors to perception?

I'm quantum, therefore I am

ZEEYA MERALI

WITH its triumphant descriptions of a range of subatomic phenomena, quantum mechanics is one of the most successful scientific theories of all time. Now it holds out the tantalising prospect of explaining one of the great mysteries in biology: the nature of consciousness. It may even explain why dreams are dream-like.

These hopes stem from a quantum model of consciousness developed by Efstratios Manousakis of Florida State University, Tallahassee. It is inspired by the "image flips" the brain makes when faced with an ambiguous image such as the one above, which can look like either a vase or two faces. Psychologists have long been fascinated by the fact that the brain cannot consciously perceive both versions simultaneously.

Understanding how the brain switches between these versions might shed light on how the conscious experience is generated. "If we can pinpoint what is different about the brain when someone is conscious versus unconscious of the image, we could solve one of the biggest questions left in science," says Olivia Carter, a visual psychologist at Harvard University.

Image flips are especially pronounced when the brain is simultaneously presented with different images at each eye, setting up a "binocular rivalry" (see Diagram). In experiments using this set-up, participants describe how the picture they perceive periodically flips from a house to a face. Researchers can record the time between flips, and use magnetic resonance imaging to measure the associated neural processes in the brain.

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The flipping seen in binocular rivalry reminded Manousakis of the quantum behaviour of particles. According to quantum mechanics, a particle such as an electron does not have clearly defined properties. Rather, it exists in a multiplicity of mutually contradictory states represented by a wave function. It is only when an observer measures a property that the wave function collapses into one of these options. This is the phenomenon on which Manousakis based his model.

Putting theory to the test

Quantum models of consciousness are not new, and Carter says they tend to make psychologists groan. One of the most famous was suggested in the mid-1990s by mathematician Roger Penrose at the University of Oxford and Stuart Hameroff, an anaesthesiologist at the University of Arizona, Tucson. In their scenario, consciousness arises from quantum computations carried out in protein assemblies called microtubules inside the brain's neurons. But unlike this and other previous models, Manousakis's is testable.

In an analogy with quantum mechanics, Manousakis defines two separate brain states: "potential consciousness" and "actual consciousness". He represents potential consciousness – the state in which the brain receives both images simultaneously – as a quantum wave function. According to his model, actual consciousness occurs when this wave function collapses and the brain perceives one of the two images. The process then begins anew, with another wave function of potential consciousness evolving that collapses in its turn, allowing the participant to perceive the rival image.

To set the values of the parameters in his model, Manousakis used the rates at which neurons fire in the brains of people taking part in binocular rivalry experiments, along with the rates they reported between perceived image flips. From these he calculated a value for the characteristic frequency controlling the quantum processes that may underlie consciousness in the brain (www.arxiv.org/abs/0709.4516).

To test the predictive power of the model, Manousakis used data from similar experiments conducted on people who later turned out to have been tripping on the drug LSD at the time. In these subjects, the neuron firing rate was slower, and when this was fed into his quantum consciousness model it led to a different prediction for the pattern of image-flip rates that the subjects should see. Sure enough, these predictions matched what the subjects reported they had seen.

Manousakis has also derived predictions for how periodically removing the image from view affects the perceived image-flip rate. He hopes psychologists will test them experimentally.

Franco Nori, a quantum physicist at the University of Michigan, Ann Arbor, who has in the past been sceptical of attempts to find a quantum underpinning to consciousness, says Manousakis has made him change his mind. "This is different, its logic is impeccable," he says. Nori is particularly impressed by the LSD results. "This is a remarkable effect that might prove that consciousness and quantum theory are intimately connected," he says.

Henry Stapp, a physicist at the Lawrence Berkeley National Laboratory in California who derived his own theory of quantum consciousness, believes that Manousakis's work could have profound implications. "If it

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is correct, this is a landmark paper that for the first time uses quantum mechanics to elucidate brain dynamics and both matches existing experimental data and provides testable predictions," he says. When it comes to the possible mechanism for quantum consciousness, however, Stapp sounds a note of caution. He points out that physicists trying to build quantum computers have found it difficult to maintain quantum states, as they are quickly destroyed when they interact with their environment. "Critics often argue that for this reason such large-scale quantum states simply can't survive in the brain for long enough to be involved in thought processes," he says.

Carter welcomes Manousakis's input to psychology from physics but suspects most neuroscientists will need more convincing. "I really want him to get to the heart of how these timings translate to what I experience, when I experience consciousness in general," she says.

Hameroff suggests that the potential-consciousness state corresponds with our experience of the subconscious mind, which we tap into in dreams. Unconscious possibilities such as dreams resemble quantum information, he says, with their "multiple coexisting possibilities, timelessness, hidden meaning and bizarre logic".

He does not, however, think Manousakis's model is enough to explain the origin of consciousness, as it requires some form of external consciousness to be in place to observe the quantum state to cause it to collapse. By contrast, in the Penrose-Hameroff model, quantum states within microtubules can collapse without any need for external consciousness. He also notes that the numbers Manousakis has calculated for the frequency of oscillations in binocular rivalry fit well with the Penrose-Hameroff model and could be created using quantum states spread over microtubules from around 1000 neurons.

Among those who remain unconvinced by the whole idea of a quantum basis for consciousness is Hugh Wilson, a visual neuroscientist at York University in Ontario, Canada, who is also trained in physics. "The brain is a macroscopic object," he says. "Just as quantum processes aren't significant in determining the behaviour of other large objects, such as baseballs, I don't think they are significant in determining the workings of consciousness." ●

SIX LEGS, TWO EYES, ONE PHOTON

Can you turn a cockroach into a quantum photon detector? Patrick Suppes at Stanford University in California is attempting this feat to determine whether quantum mechanics really could be at work in the brain.

Quantum mechanics isn't usually invoked to explain how the eye and the brain respond to incoming light. Even in dim light, our eyes are swamped by photons, and the laws of classical physics are enough to explain how our brains respond to its intensity. Some insect eyes are much more sensitive, however, and it is possible that they can pick out single photons, Suppes says.

Suppes and Jose Acacio de Barros of San Francisco State University in California have devised an experiment to test this. Cockroaches are at home in very dim environments, says Suppes, who presented his plans at the Quantum Interactions conference at Stanford earlier this year. The researchers intend to teach the cockroaches that they will receive a reward if they move towards a light source. They will then fire single photons from a laser at these "Pavlov cockroaches" to see if they react.

A positive result will show that quantum phenomena can be picked out and manipulated by the brain, Suppes says. "We don't usually give insects credit for walking on the edge of the quantum-classical divide," he adds, "but we may soon have to."

WHICH EYE WINS?

Simultaneously presenting different images to each eye allows psychologists to measure "binocular rivalry" in the brain. The phenomenon has parallels with the way quantum particles behave