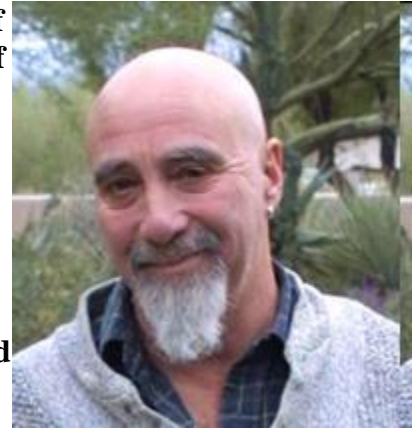


Naughty Quantum Robot!

[Stuart Hameroff, M.D.](#), is a doctor of medicine, a professor of anesthesiology and psychology, as well as associate director of the Center for Consciousness Studies at University of Arizona. Through a collaboration with mathematical physicist, Prof Sir Roger Penrose, Prof Hameroff is leading the assault on mainstream thinking about the human mind and how it is that we come to *be*. Forget space exploration. Forget biotechnology. Forget nanobots. Forget sea monkeys. The final frontier of science is reading this article right now - and there's a very good reason why physicists call it "the hard problem"...



Prof Hameroff was kind enough to take time out of his busy schedule to talk to [ObjectMonkey](#) - which surprised me, too. (What *was* he thinking?)

ObjectMonkey: The thing that really caught my attention in your work is the notion that our conscious minds might not be a product of pure computation - well not in the sense that computer programmers might know it. What is it that makes us more than just "naughty robots"?

Stuart: First, what are we talking about? What is consciousness? I mean it to be our inner life, experience, what it is like *to be*. Philosophers call the raw components of conscious experience *qualia*.

Why SHOULD computation produce consciousness? The mind has always been compared to the contemporary vanguard of information processing. Last century the mind was like a telegraph switching circuit, then more recently a hologram. Now it's a computer, and soon will be likened to a quantum computer. A computerized robot may have a nice sensory processing system to produce a representation of the external world. But who/what is observing that representation?

My toaster has a little computer. The thermostat on my wall computes. I don't believe either of them to be conscious. But OK, an A.I. type might say, well when you get to a critical level of computational complexity, consciousness emerges. There are emergent phenomena - new, novel properties emerging from simple interactions in a hierarchical system, like a candle flame from gas and molecular interactions, wetness from water molecule interactions, hurricanes and tornadoes from air and dust molecule interactions. So maybe consciousness emerges from simple interactions among neurons. But none of those examples are conscious (at least I don't believe them to be). And there is no predicted threshold or transition for consciousness.

Some will say, well when we understand the organization of the brain, we'll have consciousness. But even if you simulate the activity of every neuron, every synapse, every ion channel, every molecule in the brain, why should that produce consciousness? It might, but that's just a supposition based on the lack of a better idea.

ObjectMonkey: How did you become involved with Roger Penrose? (or should that be Prof. Sir

Roger Penrose? Or Sir Roger? Or just "Sir"?)

Stuart: Well, Roger HAS a better idea. (He's completely non-egotistical, and was embarrassed, though appreciative when he was knighted. When you get to know him, he's just "Roger"). He suggested (arguing from Gdel's theorem) that to account for human choices which are not strictly algorithmic, nor random, one needed a particular type of quantum computation in the brain.

The idea was that quantum superpositions of information states (quantum bits or qubits) in the brain would reach threshold for his (proposed quantum gravity mediated) reduction, and that the collapse or reduction would result in choices of classical states which would be neither completely algorithmic, nor random, but include influence by Platonic information embedded in the universe. He called this type of choice non-computable, and argued that it was characteristic of human conscious choices and perceptions. I've just reduced several hundred pages of detailed logical arguments into a few sentences, so I'd suggest one read his books.

But he didn't have a particularly good biological candidates for his qubits, and suggested that perhaps neurons could possibly be in quantum superposition of both firing and not firing. I had been studying neurons and structures inside neurons called microtubules which I believed to be ideal information processors supporting neuronal activities from within. A neuron is far more complex than a simple on-off bit state. If you think about a single cell like a paramecium which can swim, learn, avoid predators, find food and mates and have sex, it has no synapses. It's just one cell. It uses its microtubules as information processors.

My point had been that each neuron, with roughly 10 to the seventh microtubule subunits switching every nanosecond provided 10 to the sixteenth operations per second PER NEURON. A.I. types trying to simulate the brain had been assuming 10 to the eleventh neurons, 10 to the 3rd synapses per neuron, switching every 10 milliseconds max for a total brain capacity of roughly 10 to the sixteenth operations per second. So I was saying each neuron matched what they were targeting as total brain capacity. I was (and am still) rather unpopular among A.I. types.

But people would say to me "so how does that explain consciousness?" And of course, it didn't.

So I thought maybe Roger had the mechanism and I had the biological structure, and that microtubules might be his quantum computers. So we teamed up to develop a model.

ObjectMonkey: The thing that spurred me on to find out more about your work was a BBC documentary I saw a couple of years ago. I may have got this wrong - I usually have - but didn't the program suggest there was clinical evidence that our consciousness might "leak out" of the brain under certain conditions? What was the nature of this evidence?

Stuart: Several clinical studies had looked at patients who had cardiac arrests but were revived and then reported "out of body" experiences. The percentage was about 17 percent of all cardiac arrest cases. They nearly all reported the same things - white light, sense of calm, tunnel. In some cases they reported floating above the room, or out into the hospital waiting room observing their

family. In some cases they reported events or conversations which occurred when their brain was not functioning, and/or in another room.

The BBC asked the clinicians who conducted the studies how they could explain this, and they said "ask Penrose and Hameroff". I told them that, according to our model, consciousness was occurring at the level of quantum gravity, at the fundamental (fundamental) level of space-time geometry at the Planck scale, where - we propose - proto-conscious qualia and Platonic information are embedded. So when the brain metabolism fails and microtubule quantum coherence is lost, the quantum information is no longer confined to the brain and "leaks out" into space-time geometry at large, still bound by quantum entanglement.

ObjectMonkey: Other reading I did into the nature of consciousness and particularly the relationship between physics and mind have suggested that "materialism" - the belief that the mind is a product of physics - is a prejudice. Indeed, in Roger Penrose's book "The Large, The Small, and The Human Mind" he admits that it is. Have you ever entertained the converse view that physics may be a product of consciousness? Or is that just TOO weird?

Stuart: I agree that the idea that the mind is a product of physics "as we know it" is a prejudice, just like the idea that the mind is a product of computation. We need new physics, like Roger's ideas of quantum gravity objective reduction in which consciousness is a process occurring on the edge between the quantum and classical worlds.

Idealism is the notion that the mind produces the world. Bishop Berkeley is the philosopher most associated with this idea, which is similar to Hindu beliefs. Positivism is the similar notion that the mind constructs our reality. The Copenhagen interpretation of quantum mechanics is basically positivist.

ObjectMonkey: Another very bizarre idea to have emerged from your field of research is how our perception of time might not be quite as linear and objective as we think. How can I *feel* my feet hit the ground at the same time I *see* them hit the ground? Surely my sense of touch is much slower than the speed of light?

Stuart: Good question. There are three types of answers. One is that the fast (visual) information is delayed to match the slow, tactile information. Thus we are "living in the past" slightly. This would be disadvantageous from an evolutionary standpoint. (Imagine two boxers, one a half second slower reacting.)

The second is that we see and feel etc separately, out of kilter, but just remember the sensations as being synchronized. This is the "Orwellian revisionism" idea put forth by Dan Dennett. Our conscious sense of reality is an illusion.

The third was suggested from experiments by Ben Libet in the 1970s on patients having brain surgery while awake, their scalp and skull numbed. Libet would, for example, stimulate their left pinky finger, record from the corresponding right sensory cortex, and ask them precisely when they felt the stimulus (he had a clever way of eliminating reporting delay). He would then directly stimulate that part of right sensory cortex and ask when they felt it. You would expect

that the finger stimulation would be delayed, and the cortical stimulation would be felt immediately. But the results were just the opposite. The finger stimulation was reported immediately, and the brain stimulation was delayed. Libet concluded that the brain refers information backwards in time. So in your walking example, the slow tactile sensations from the feet are referred backwards in time, i.e. from the near future to the present.

If consciousness is a series of quantum state reductions, then no problem, as time is indeterminate between reductions. Another way of looking at it is Aharonov's idea that each reduction sends two vectors of information, one forwards and one backwards in time. This referral from the near future may be the only way to explain a baseball batter hitting a 100 mile per hour fastball from 60 feet. Someone looked at that and showed that it is impossible by conventional neurophysiology. It may be the same for cricket.

ObjectMonkey: Some would argue that if you want to find a civilization that understands mass-energy equivalence, you just look for the mushroom clouds. What might be the signature of a civilization that has a practical understanding of consciousness?

Stuart: Well, they could construct artificial media for consciousness, using e.g. fullerene-based quantum computers. So when the body died, consciousness could be transferred for an indefinite existence, perhaps operating robots. But on the other hand if it were appreciated that consciousness persists anyway in fundamental space-time geometry, there would be no need for such artificial media. It could be a very content, spiritual society.

ObjectMonkey: I recently read Rupert Sheldrake's book "The Sense Of Being Stared At", which puts forward clinical evidence that the mind can extend beyond the brain while we're awake. Are you familiar with his work? Is it just possible that the effects you talked about when a patient's brain metabolism fails might also occur under other circumstances?

Stuart: I am somewhat familiar with Rupert Sheldrake's work, and would very much like to see clinical evidence that the mind can extend beyond the brain. I'll have a look at it. Thanks.

I do believe it is possible, and may occur all the time. Phenomena such as telepathy can be explained by quantum entanglements which are inherently non-local. The trick is how two people can become entangled. But fundamental space-time geometry may be inherently non-local, and so our sense of spatial separation may be somewhat illusory.

ObjectMonkey: President Bush - bless his little cotton socks - has announced recently a renewed effort to put men back on the Moon and eventually on Mars. If you had that kind of budget at your disposal, what would you do with it?

Stuart: Well, I'd save Social Security, boost healthcare, education and the environment. And I'd try and find a cure for arrogance. As far as science, the only reason Bush wants to put men on the moon and Mars is most likely military. He's worried the Chinese will get there first. I'd revamp the NIH, NSF and other funding agencies so researchers aren't herded into cubbyholes.

ObjectMonkey: Will Quantum Computers ever be capable of consciousness, or is there still

something missing from the mix?

Stuart: The key is Penrose objective reduction, sustaining superpositions long enough (avoiding decoherence via isolation or other means) to reach threshold for self-collapse, thus connecting to fundamental space-time geometry. Technological quantum computers as presently envisioned will reduce by measurement, introducing some randomness which can be averaged out by redundancy.

The threshold for consciousness is given by the indeterminacy principle $E = h/t$, where E is the gravitational self energy of the superpositioned mass, h is Planck's constant (over 2π), and t is the time until reduction. E and t are inversely related. So, a large superposition will reach threshold for a conscious moment quickly, and a small superposition will require a long time. In both cases the superpositions must be isolated from environmental decoherence. An isolated superpositioned electron would reach threshold and have a conscious moment (albeit a rather dull one) only after 10 million years. An isolated one kilogram superposition (e.g. Schrodinger's cat) would reach threshold after only 10^{-37} seconds - too fast to notice.

In the brain we have the right balance - an amount of superpositioned tubulin proteins in microtubules which can be isolated inside neurons to reach threshold every 25 milliseconds or so, i.e. 40 times per second, corresponding with the well known coherent 40 Hz brain oscillations.

Quantum computers as presently designed will have superpositions of electrons, so E will be small and t will be very long. So they won't reach threshold before they are measured. However it is conceivable that a quantum computer using fullerene technology could have enough superpositioned mass - a large enough E to do so, to reach threshold for consciousness in a reasonably short time.

ObjectMonkey: Have you ever watched "I'm a Celebrity... Get Me Out of Here?" Is it just possible that some people aren't conscious at all - even though they may appear to be? Is it possible to appear self aware when you're really not? Could consciousness be artificially suppressed?

Stuart: Philosophers call such entities "Zombies". They may have complex behaviors, but no inner experience (like the android Commander Data on Star Trek). It has occurred to me that materialist philosophers like Pat Churchland and Dan Dennett may in fact be zombies. At the conferences "Toward a Science of Consciousness" we have every two years in Tucson (the next one coming up in 2 months, April 7-11, 2004 - see <http://www.consciousness.arizona.edu/>) Dave Chalmers and I have held a consciousness poetry slam and usually do renditions of what we call "The zombie blues", sung to the tune of George Thorogood's "Bad to the bone", (you know, a verse then, Dah DA, dah DUM). The first verse starts out

"I look like you look",
audience: Dah DA, dah DUM

"I do what you do"

Dah DA, dah DUM

"But I'll never know"

Dah DA, dah DUM

"What its like to be you!"

Dah DA, dah DUM

"That's cause I got the Zombie Blues"

And so on

Participants are encouraged to make up their own verses and perform them. Several verses have been a bit off color, based on the idea that zombies can have sex, but cannot have orgasms. Actually I suspect that sexual experience may have been the first qualia in evolution. What better way to promote reproduction and survival of the species?

ObjectMonkey: Roger argues in his book that creativity and intuition are non-computable products of consciousness. Is there some aspect of our brains that might make some people more creative/intuitive than others?

Stuart: A host of things might help, like native intelligence, genetics, environment, personality, all of which would allow some to take more advantage, be more tuned in to the Planck scale Platonic realm. Or it may be an isolated trait, like savants. Julian Jaynes wrote in "Origin of consciousness and breakdown of the bicameral mind" that, prior to a few thousand years ago, people lacked a "self" and listened to voices in their heads. Maybe they were tuning into the universe. Some still can, but others drown it out. There are implications for spirituality as well.

ObjectMonkey: Out of the following, which would you say is the greatest invention of the modern age?

- a) TV
- b) Computers
- c) Furbees
- d) X-Ray Specs

Stuart: I'm not sure what a Furbee is, but I wrote a chapter in a book "Greatest Inventions of the Past 2000 Years" edited by John Brockman. I nominated anesthesia, invented in the mid 19th century. What if you needed surgery, or even possible needed surgery and there was no anesthesia? Among your list I'd go with computers.

ObjectMonkey: Currently, I'm reading "The Very Hungry Caterpillar" by Eric Carle. I like the pictures, but it's a little heavy going in places. What book are you reading at the moment, and who do you get to help you when you get stuck on a big word?

Stuart: I'm in the midst of several, laying around the house. They include Al Franken's "Lies and the lying liars who tell them: a fair and balanced look at the right", "The coming anarchy" by

Robert Kaplan, "God and the new physics" by Paul Davies, and one whose name and author escape me, but is about a traveling freak show family whose members' self esteem relate to the degree of their anatomical abnormalities. The last book I finished was "The DaVinci code".

If stuck on a word I'd ask my girlfriend Samantha. I'll ask her what a Furbee is.

ObjectMonkey: What's your favourite restaurant, and why?

Stuart: A hole-in-the-wall Mexican restaurant in south Tucson called "El Torero". Its got great chimichangas, cold beer, bullfight posters and a huge swordfish on the walls.

ObjectMonkey: In the interests of science, I've devised some ingenious experiments which you might like to try:

a) Wear a tweed jacket and a bow tie to work. Smoke a pipe and offer anyone who comes in to your office a glass of sherry. Have a pot of tea and a selection of cakes delivered at 4pm prompt every afternoon. Refer to everybody as "my good man" or "my dear lady". Observe the reactions of your colleagues and write them down in a little book. When the book is full, count the number of times you used the word "stare". If my theory is correct, you will have used it more than once, but less than a billion times.

b) Run up and down stairs many times until you become very tired. If my estimates are accurate, this should take between 1 and 360 minutes.

b) Soak all your clothes in vinegar. If my predictions are sound, they should last longer.

Let us know how you got on.

Stuart: I'll get right on them.

ObjectMonkey: After a hard day's being, here at Monkey Towers we like to glue almonds on to the lapels of our zoot suits, drink precisely 9.4 hectares of Crme de Menthe - which you might want to jot down - and then head off in our second-hand Batmobile to Matt Damon's holiday caravan for a game of Buckaroo. How do you like to wind down?

Stuart: Exercise. I play - not that well - basketball, golf and tennis.

ObjectMonkey: How many times have you seen Star Wars?

Stuart: Not sure, but I actually read the original book way back when. The cover notes said they were going to make it into a movie. I said "No way". The same thing happened with Jurassic Park.

ObjectMonkey: If you could have your time over again, how bored would you be? ("Yeah. Been there. Seen it. Done that. Yada yada yada...")

Stuart: If I don't see you in the future, I'll see you in the pasture.

ObjectMonkey: Lastly, and most importantly - when was the last time you ate candy floss? (I believe you call it "cotton candy")

Stuart: Probably at a University of Arizona Wildcat basketball game when we were safely ahead of the opponents.

The original article as posted by Object Monkey can be found at

<http://www.objectmonkey.com/?A=getcolumnpiece&Ar=p=43%5Ec=6%5Ei=15%5E>