Hot on the trail of consciousness in brain and machine

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From brain-scanning experiments to self-aware robots, two books explain how far we've really come in the quest to crack consciousness

"NOWHERE in science have so many devoted so much to create so little consensus," writes physicist, author and TV presenter Michio Kaku of consciousness research. So why, then, do we have yet another brace of books on the topic, one from cognitive psychologist Stanislas Dehaene and one from Kaku himself?

In Dehaene's case, the encouraging answer is that he sees progress in understanding consciousness coming out of his lab at the Cognitive Neuroimaging Unit in Saclay, near Paris – France's most advanced brain-imaging centre. *Consciousness and the Brain* is his excellent catch-up on the latest research, but there is a caveat: read a chapter at a time because it is jam-packed with intuition-altering experiments. In between, enjoy Kaku's madcap tour of the world's top brain labs, served up with whimsical insights in *The Future of the Mind*.

Dehaene expresses his own view of consciousness simply: "Consciousness is brain-wide information sharing." His book tells the story of why he thinks that and what it might mean. He begins his travels on a path pioneered by two luminaries, Francis Crick – on his second, post-DNA career – and Christof Koch. They were searching for unique "neural correlates of consciousness"; that is, the things that happen in particular parts of the brain only when you are consciously aware of something.

Dehaene has been making progress by presenting volunteers with visual stimuli cleverly designed so that they teeter on the threshold of conscious awareness. We learn that an effective method is to flash a stimulus image very quickly, sandwiched in time between a pair of different, "masking" images. If the duration of the stimulus – a word, for example – is carefully adjusted, then sometimes the word will get through to conscious awareness, and the volunteer can shout it out. Sometimes the volunteer will perceive nothing more than a flickering pattern. While conscious awareness shifts between on and off, scanners look for changes inside the brain and EEG machines pick up electrical signals from its surface. These data map out differences in the brain between the two states.

As his results mount up Dehaene gets excited, because he sees an "avalanche in the brain". When the threshold for conscious awareness is crossed, electrical activity in the higher visual centres is suddenly amplified and it spreads like a tsunami into regions of

the parietal and prefrontal cortex – high-level areas of the brain which are never reached by the gentle waves of unconscious activity. Activation surges on into a much larger expanse of cortex, and distant brain regions start showing tightly correlated activity.

Over the same period, EEG picks up a characteristic wave of electrical activity, dubbed "P3". It looks as though different parts of the brain are rapidly sending long-distance messages back and forth, and synchronising views.

To make sense of this sudden large-scale burst of activity, Dehaene takes the "global workspace" model of consciousness developed by psychologist Bernard Baars and boldly extends it, identifying consciousness as the process of brain-wide information sharing. At any time, millions of short-lived mental representations of your world are being created by unconscious processing, he says. Consciousness selects one and makes it available to distributed, high-level decision systems through a brain-wide "broadcast".

The empirical facts of the brain activity we see, and the wiring of the regions which fire up, dovetail neatly with Dehaene's compelling metaphors. In the prefrontal cortex there are neurons with very long axons that connect to hubs elsewhere in the brain and which also have huge webs of dendrites that connect with many thousands of other cells. These neurons seem purpose-built to broadcast rapidly to the rest of the brain, explaining why these parts of the cortex are the first to ignite whenever a piece of information enters our awareness.

We know that much of our cortex performs very specific tasks, such as conceptualising, categorising, reacting to faces, and processing numbers. In one study, a monitored neuron consistently fired only when its owner viewed images of Jennifer Aniston!

Consciousness, thinks Dehaene, may have evolved to pick out what is relevant from this huge amount of parallel activity, and keep it active within the global workspace while different parts of the brain evaluate it. It is necessary so we can deal with one important thing at a time and enable a kind of "collective intelligence" to be reached. That would include providing access to memory and mental associations, as well as to language processors which could describe the ongoing experience, Dehaene suggests. It all takes time, which may explain why consciousness seems to run about a third of a second behind reality.

Could the rich experience of consciousness, which feels as though it brings together sensation, interpretation, memories and language, really be no more than this "global sharing of information"?

The metaphor is certainly attractive but some will disagree. For these critics, the mental "feel" of the colour red, say, won't be found by adding up the firing of brain cells which detect red, the association of red in your memory, and the labelling of the colour with a word. How the firing of cells can "feel" like something is the philosophical "hard problem" of consciousness. And it's a problem researchers think needs wholly new kinds of answers.

Kaku has a view on the hard problem, too. But before getting there, he explores everything he can think of on the future of the mind. When he was small, Kaku recalls: "I used to love taking apart clocks." From his delightfully odd book, I suspect it would still be unwise to leave him alone in your home with a screwdriver, for his curiosity is endless.

He's looking for machines that can read minds, and when he encounters the first efforts (in none other than Dehaene's lab) he wonders whether one day we might have to devise shields to block our most private thoughts.

At one stage he meets the visionary scientist Miguel Nicolelis, who has made remarkable progress at Duke University, North Carolina, in getting the brain to directly control a wearable exoskeleton designed to help disabled people walk. The two men seem to be kindred spirits. In their conversations we are flung into the future beyond mere mind melds to a "brain net" – an "internet of the brain" which transmits thoughts, emotions and ideas in real time between brains.

Kaku is enthusiastic, but not naive, and he has a knack of asking the most disarming questions and using his physicist's sharp brain to see flaws in much-touted ideas. For example, when he meets the creators of ASIMO, a robot made by Honda that can run, dance and apparently speak different languages, and asks how smart it is, the answer is that the robot is still at a primitive level, requiring lots of clever programmers to script its complex movements.

Finally, Kaku has his own take on the hard problem of phenomenal experience. In the future, he speculates, robots will be able to process a sensation, such as seeing the colour red, better than any human and even use it, poetically, in a sentence. At that point, writes Kaku, robots will rightly comment: "Perhaps humans cannot really understand the colour red with all the nuances and subtlety that a robot can."

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