11 Discoveries Taking
Science by Surprise

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1

TRIUMPH OF THE ZOMBIE KILLERS

The science of consciousness has risen from the grave

We have been to the moon, we have charted the depths of the ocean and the heart of the atom, but we have a fear of looking inward to ourselves because we sense that is where all the contradictions flow together.

Terence McKenna

To the audience's utter delight, Gustav Kuhn is performing magic tricks. He makes ping-pong balls disappear and reappear in ridiculous places. Then he explains how he did it. 'It's simple misdirection,' he says. 'I manipulate your attention by moving my hand in certain directions; you can't help but follow it with your eyes, which gives me the chance to…' He turns his head, and our gaze follows. The ball is back in his hand. We can't help but applaud.

It's unusual for an audience to be clapping this early into a scientific talk. Usually there's a smattering of applause at the end – often a manifestation of relief that it's finally over. But here at the sixteenth meeting of the Association for the

Scientific Study of Consciousness the audience is enthralled from the start.

Kuhn thinks there should be a science of magic. The effects he and other magicians create are robust, significant, replicable and, above all, useful, he says – just like good scientific results, in other words. He and his co-presenter, Ronald Rensink, another magician–scientist, think that studying what magicians do can teach us about perception and cognition (and deception), how children develop an understanding of what is possible and impossible, why magical beliefs persist and what happens when the brain develops in unexpected ways. A study of magic could help us develop new tricks for engaging and interacting with people and technology and find new angles on problem-solving. And most important of all, it might give us a window on what it means to be conscious.

Studying consciousness used to be considered the ultimate waste of time. It is, after all, a subjective phenomenon, and thus unlike anything else in science. How can I study someone else's consciousness when I have to rely on their reports? How can I study my own, when I can't get any distance from it? Somehow, that spongy matter inside my skull creates something we call consciousness, but if I probe it, I disturb it. We don't have the means to keep a brain alive outside the skull and, even if we did, would we expect to dissect a brain and find its consciousness?

In 1994 philosopher David Chalmers coined a phrase about consciousness that has become a millstone or a mantra, depending on your point of view: 'The Hard Problem'. Consciousness 'escapes the net of reductive explanation,' Chalmers says. 'No explanation given wholly in physical terms can ever account for the emergence of conscious experience.' In other words, consciousness can't be explained by reverse-engineering the brain. You can't build a brain and expect to trace where its consciousness comes from. Consciousness is different in character from

the set of all physical facts – it stands apart. That's why, he said, it is possible we are surrounded by undetectable zombies.

Any number of movies have described the onset of a zombie apocalypse. In not one of them has the hero used sleight-of-hand tricks to give their loved ones time to get away. That might seem like a banal observation, but it raises an interesting question about the nature of consciousness – and Chalmers's argument. Would a zombie be amazed and distracted by Kuhn's conjuring? What do zombies make of magic?

To be fair to Chalmers, he wasn't talking about the familiar, flesh-hanging-off, undead, food-obsessed zombies of science fiction. After all, they're easy to spot, with their lumbering gait, their insensitivity to pain or injury, their inability to communicate with or relate to others, and their glassy-eyed stare. What we're talking about is the perfect copy of a normal human, one that, from the outside, looks no different to you or me. This zombie walks normally; it can hold a conversation. It will even tell you it is feeling something. But the first question you have to ask yourself is how you could tell if it is telling the truth. You couldn't.

You can say exactly the same about your work colleagues. You, as Descartes pointed out, know you are conscious – '*cogito, ergo sum*', I think, therefore I am. But how do you know anyone else is conscious? All you have to go on is the fact that they appear to be the same as you. They react to stimuli such as a punch in the arm in the same way you would. Ask them a question and they respond in reasonable ways, and in a reasonable time. But if you ask them what they are experiencing, you have no way of knowing if they are just telling you what they think you expect them to say. They might not feel anything – they might just know what a human being is expected to be feeling in that situation, and report that.

This is the zombie hypothesis: that everyone around you might lack any self-awareness, any sense of self, and you wouldn't necessarily know it. Bringing it closer to home, imagine a version of you that is exactly like you, physically and mentally, so they look, act and speak like you, even thinking like you to give the same answers that you would to any question someone cared to pose. The difference is that this version of you has no awareness of themselves; they are, effectively, an automaton.

The fact that you can imagine this, Chalmers says, means it is theoretically possible. And so, he argues, consciousness must be something extra and above the physical material and processes of our brains, something that sits on top of our sensory perceptions, our reactions to them and our reporting of them.

That 'something' makes us more than a zombie. This difference, we could say, defines consciousness. It's that quality that gives us a sense of self, of what we are feeling, of introspection, examining and questioning our place in the world. It is, perhaps, what makes us amazed and entertained by magic tricks. It is what makes us laugh and cry. It is, you might say, what makes us human. Philosophers have longed to distil this essence of self-awareness for centuries. The exciting thing is that science is now, finally, giving us ways to probe the issue that involve more tricks than just thinking about it. And it appears that our scientific insights have killed the zombie. We can stand astride its corpse and declare that we will win in the end because we now see that consciousness must have a physical root and, consequently, will indeed succumb to science.

All of the work scientists have done on consciousness so far has led us to a handful of models that seek to exemplify what is going on inside our heads. Two are considered most promising.

One is the global neuronal workspace theory, a combination of insights from psychology and neuroscience. It suggests that all the inputs from the outside world – touch, taste, vision, hearing and so on – are first processed unconsciously. Very few of these inputs will get your attention; this only happens when there is enough subconscious processing going on to trip a switch that activates the areas of the brain concerned with conscious processing. Neuroscientist Daniel Bor describes it as 'a spotlight on a stage, or scribbles on a general-purpose cognitive white board'. Put simply, it's putting our short-term working memory to use – although those memories last only a couple of seconds, it's long enough to draw on them when necessary.

Its chief competitor is known as information integration theory. This model puts consciousness into the language and framing of information theory, creating datasets that add up to more than the sum of their parts. Its originator is Italian psychiatrist and sleep researcher Giulio Tononi. He is a controversial figure in many ways – though his theory is barely on its feet, he has declared that it could lead to a universal consciousness meter that would measure the 'level' of consciousness of anything from a worm to a computer network. However, information integration theory is about the whole network of neurons, and makes no attempt to explain what is going on in the individual physical structures of the brain. That means it doesn't much lend itself to the kinds of simple experiments used to test the global workspace theory. That said, it has some heavyweight fans. 'It's the only really promising fundamental theory of consciousness,' Christof Koch told *New York Times* writer Carl Zimmer.

In the end, though, we have to admit that decades of development have resulted in theories of consciousness that are still somehow unsatisfying. Psychologists and neuroscientists are, in many ways, like Darwin aboard the *Beagle*: they are still gathering

specimens and making observations of interesting things done by the brain. They haven't yet, if we're being honest, got very far in pulling it all together into a coherent theory, a simple idea that explains the subjective experience of being conscious of what is around us, of thinking about things, of how the stuff of our brains creates a different experience from the zombie's existence without awareness. And that is exactly what led researchers to kill the zombie.

The leader of the zombie-hunters is unquestionably Tufts University philosopher Daniel Dennett. His strategy is remarkably simple. Perhaps there is, he suggests, no such thing as consciousness, that this ongoing awareness and sense of thinking about the world is actually an illusion. Perhaps our brains are fooling us into thinking there's some overarching narrative to our existence.

In 1991 Dennett published a book with an audacious title. *Consciousness Explained* was greeted with charges of hubris, but perhaps the detractors should have waited. In the book's 'Appendix for Scientists', Dennett made a prediction that, if his theory was right, we should be blind to many subtle changes in our environment. Change-blindness would exist, he said, because the conscious visual experience is not a true reflection of what is actually in front of individuals.

Dennett's idea is similar to the premise of the movie *The Matrix*, where humans have a conception of reality that is actually a carefully stitched simulation fed directly into their brains by a race of machines. In Dennett's view, there are no machines, only the brain. But, just as the machines' simulation sometimes has glitches, if we look carefully enough at our world, we'll see the brain's stitches. It turns out he was right.

Ronald Rensink has done a lot of the work to prove Dennett's hypothesis. He has carried out a series of experiments that show people missing seemingly obvious things right in front of their

eyes. To understand why, we can start with the issue of foveal saccades.

The evolution of the eye and the visual processing system has had to cope with a number of efficiency measures, but perhaps the most remarkable one is that, even without taking blinking into account, for around four hours of every waking day there is no visual information being processed by your brain. That's because your retina takes in a full image of the world on a patch of densely packed photoreceptor cells that is about one millimetre in diameter. This is the fovea centralis, which records detail and colour from the world around you. The thing is, it only takes that reading from an area that's about the size of your thumbnail held at arm's length. Your vision captures everything else in front of you at that moment at a much lower resolution, and in monochrome. Go ten degrees off centre and you're capturing about 20 per cent of that maximum amount of visual information. In other words, most of what you see is recorded in a blurred black-and-white image.

The reason you're not aware of having such a 'lo-fi' view of the world is because your eye is constantly flitting about, capturing as much of the visual field as possible on the fovea's receptors. Roughly three times a second, for about 200 milliseconds each time, you record a high resolution image, and then your eye moves again. In between these saccades, or jerky movements, your brain turns off in order to prevent you registering the blurred image of the movement. In a paper published in *Trends in Cognitive Sciences*, David Melcher and Carol Colby showed that spending 100 milliseconds 'offline' roughly 150,000 times per day adds up to four hours of blindness. You don't notice it because your brain stitches together the processing it *has* done, creating the illusion of seamless visual perception. But that's nothing compared to the illusions exposed by change-blindness researchers.

Working with his colleague Daniel Simons, Dennett has performed some stunning (and hugely entertaining) experiments demonstrating how the smooth flow of our visual consciousness is an illusion. Starting with photographs that swapped between two views, for instance, only 50 per cent of subjects noticed when the heads of two men were swapped. No one noticed when the men swapped their differently coloured hats. Our 'sparse visual representations' meant that when subjects watched a film of an actor rising from a chair, and changes in camera angle were used to swap one actor for another, 67 per cent of people didn't see the change. The same thing happens in the real world. In one classic experiment, an actor stops someone on the street to ask for directions. During their conversations, two other actors carrying a door rudely barge between them. While the door obscures the subject's view, a fourth actor replaces the first. In roughly 50 per cent of cases, the subject then carries on giving out directions, oblivious to the fact that the person they are now talking to is different from the first.

It's not because the actors appear to be similar: even if those two actors have different clothing and haircuts, and different heights, builds and voices, half the time, people just don't notice the change.

You can even exploit change-blindness. Film editors, like magicians, use tricks and distractions. Edward Dmytryk's seminal book *On Film Editing* makes it clear that sometimes you can make an audience blink, which gives you one-fifth of a second to change the camera viewpoint, or the focus of a scene, without any of the viewers noticing. He suggests the sound of a door slamming, but any sharp sound – a gunshot, for example – will do it. 'The cutter makes his cut as the viewer's eyes blink or are caught by the movement on the screen, much as a magician masks a move requiring camouflage by distracting the eyes of his

audience with the broad sweep of his cape or a sharp movement of his "decoying" arm,' Dmytryk says.

Even movie editors are change-blind, though. That's where those cinematic howlers come from: there's a scene in the movie *Goodfellas*, for example, where a child is playing with a set of blocks. As the cuts come and go, so do the blocks – they change colour, or are stacked in different orders. In another scene from the same movie, a loaf of bread mysteriously disappears. Clearly no one noticed before the film was released, and most cinema-goers didn't notice, either. There's a scene in *The Wizard of Oz* where Dorothy's ruby-red slippers turn black for a moment. In the movie *Avatar*, one scene features golf balls that appear to move around the green of their own accord.

Such observations are unquestionably fascinating and fun, but they have a serious side. Skilled experimenters can use them to show that we are not paying proper attention to the world, we have little memory for the details of what is going on around us and we simply don't see what we think we see. Our conscious experience is not at all what we think. Consciousness has all the traits of something that evolved to give a 'just enough to survive' outlook on the world; it is a product of our senses, nothing more, nothing less. It is certainly not appearing to be something extra that is 'on or off' – human or zombie. It's more like a sliding scale. And that has significant implications – not least for the animals with whom we share the planet.

On 7 July 2012 a group of consciousness researchers gathered at Churchill College, Cambridge. They weren't philosophers, but cognitive neuroscientists, neuropharmacologists, neurophysiologists, neuroanatomists and computational neuroscientists. Together, they made a 'Declaration on Consciousness'.

The subject of their declaration was the abundance of new evidence concerning the 'neural correlates of consciousness'. The signals we can read from the brain, which tell us something about the subjective experience of the creature whose brain is being studied, are now showing that emotions and feelings abound in non-human animals and young humans. Invertebrates such as insects and octopuses have them. Birds have them: 'evidence of near human-like levels of consciousness has been most dramatically observed in African grey parrots,' the researchers declared. Zebra finches clearly experience REM sleep – they dream, in other words. Magpies can recognise themselves in the mirror just as well as great apes, dolphins and elephants do.

With all the evidence to hand, the researchers made their statement: 'non-human animals have the neuroanatomical, neurochemical, and neurophysiological substrates of conscious states along with the capacity to exhibit intentional behaviours… humans are not unique in possessing the neurological substrates that generate consciousness. Non-human animals, including all mammals and birds, and many other creatures, including octopuses, also possess these neurological substrates.'

They signed their written deposition, slightly oddly, in the presence of Stephen Hawking. But perhaps it was a good choice. Who would claim that Hawking, a brilliant cosmologist, isn't conscious? He is undoubtedly very much aware of his surroundings, capable of feelings such as joy and sorrow, and a cogent and fearsome thinker. Strip him of the technology that allows him to communicate, however, and of the human carers that meet his physical needs, and it might be possible to plausibly deny his consciousness.

That is why this area of research is so important. An understanding of consciousness is key to relating properly to animals, but it will also help us face our problems with the biggest human dilemma: death.