

NEUROSCIENCE

The Eternal Silence of Neuronal Spaces

Stanislas Dehaene

Consciousness is, quite literally, mind-boggling. From the objective, third-person perspective of neuroscience, the subject consists of clarifying how three pounds of brain flesh, a mere assembly of molecules, can ever give rise to conscious mental states, feelings, and a sense of self. But every neuroscientist is also a human being, a self with a point of view, who suffers life's miseries and can therefore ponder the mysteries of conscious and unconscious thoughts from a privileged first-person perspective. Whence this unbearable toothache? Why the nostalgia of a lost love? Who is this I, really? Do "I" own my life, or do my genes, my brain, and my habits own me? And if so, what gives my life a meaning?

In *Consciousness*, Christof Koch, a cognitive scientist at Caltech, artfully weaves the two perspectives together. The resulting atypical science book combines a review of top-notch scientific findings with personal memories, musings, and confessions of an active, introspective, and perplexed neuroscientist.

The science itself is generally impeccable. As he has previously demonstrated (1), Koch excels at explaining, in simple and concise terms, the most recent research into the neurobiology of consciousness. Enlightening discoveries abound. With collaborators Itzhak Fried and Rodrigo Quiñero, the author initiated a remarkable search for the neuronal correlates of elementary conscious percepts, capitalizing on the novel capacity to record from individual neurons in epilepsy patients. They discovered that some neurons in medial temporal cortex fire in response to the face or name of a specific person. Critically, even for a constant stimulus, the neurons fire only when the subject reports seeing the picture and not when eclipsed by binocular rivalry or masking (2). Such neuronal observations converge nicely with brain-imaging experiments in normal volunteers to suggest that synchronous and distributed brain activity in specific higher-order brain

areas provides neuronal signatures of conscious brain states (3).

The operational knowledge of consciousness has reached the clinic. In a patient thought to be in a vegetative state, functional magnetic resonance imaging detected complex mental states that reflect a conscious mind (4), and simpler detection devices are now being envisaged. Pursuing consciousness at the cellular and molecular levels, Koch has launched a \$300-million program at the Allen Institute in Seattle to develop "brain observatories" that will dissect the microcircuitry of visual cortices in mice (5).

Koch fearlessly discusses some of the most difficult questions in the field. For instance, are animals conscious? Koch's guess is a resounding yes: his six dogs surely have conscious states—their tails, snouts, paws, bod-

ies, ears, and tongues obviously express a cornucopia of internal feelings. "Indeed," he whimsically remarks, "I often think dogs are closer to true Buddha nature than people are." Here, alas, he offers no experimental data; avowedly, only the dog owner speaks, not the scientist and even less the dog.

From dog to god is a small step. Perhaps the author's most unexpected confession is that he was a long-time devout Christian. Although those days are gone, Koch still feels strongly that life must have a purpose. In the introductory chapter, he confesses, "With perfect hindsight, I now realize that what drew me to studying consciousness was a compelling and entirely subterranean desire to justify my instinctual belief that life is meaningful." Perhaps this stance explains his strong attraction to the philosopher David Chalmers's dual-aspect theory and, especially, to Giulio Tononi's mathematical theory of consciousness as integrated information (6), which he describes as amounting to "a form of property dualism." In a curious move, our romantic reductionist now concludes that the mental and the physical compose "two sorts of properties ... that can't be reduced to each other."

The implications of Tononi's theory fill Koch with uncritical enthusiasm. He expresses his strong faith that the theory

Consciousness Confessions of a Romantic Reductionist

by Christof Koch

MIT Press, Cambridge, MA,
2012. 193 pp. \$24.95, £17.95.
ISBN 9780262017497.

BROWSINGS

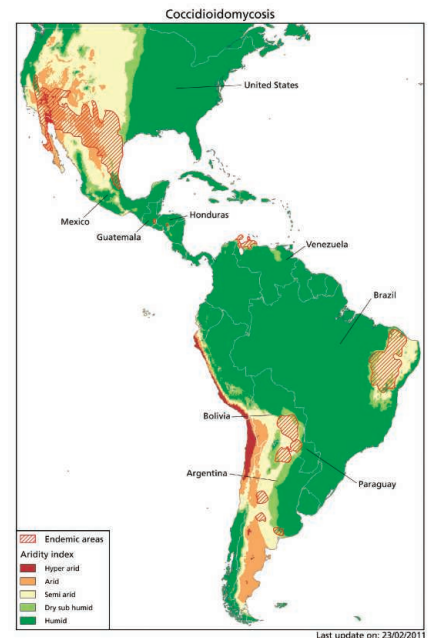
Atlas of Human Infectious Diseases. Heiman F. L. Wertheim, Peter Horby, and John P. Woodall, Eds. Wiley-Blackwell, Oxford. 2012. 308 pp. £84.99, \$130, €102. ISBN 9781405184403.

If you're interested in infectious diseases and you like maps, you'll love leafing through the *Atlas of Human Infectious Diseases*. It shows the global distribution of more than 110 diseases, from well-known scourges such as malaria and cholera to oddballs like strongyloidiasis and O'nyong'nyong virus disease. Maps have been available for many diseases, but, Wertheim notes, it's often unclear who made them or what data were used—and they frequently contain errors.

Wertheim (a clinical microbiologist working in Hanoi for the Wellcome Trust and Oxford University) didn't want an electronic atlas but a book you can draw inspiration from as you read it on the couch. The editors took five years to prepare the maps, sifting through data from countless papers, field reports, and other sources. Each map was reviewed by two experts for its particular disease. The atlas also charts underlying factors such as water and sanitation, international travel, and urbanization.

Infectious diseases are nothing if not dynamic, and freely accessible updates will appear on a forthcoming companion website. Meanwhile, Wertheim hopes that the gaps in the maps will inspire researchers to collect more data on where pathogens occur. For many diseases, Africa is epidemiology's terra incognita—as painfully large gray areas in the atlas testify.

—Martin Enserink



Coccidioidomycosis (valley fever).

will soon lead to the clinical application of a consciousness-o-meter for coma patients, although Tononi's measure of consciousness Φ remains essentially noncomputable. Building on the theory, the author offers a grandiose panpsychic vision, which he finds "terribly appealing for its elegance, simplicity, and logical coherence." Every organism, even bacteria, would possess some degree of consciousness. The logical coherence escaped me: Only two chapters earlier, Koch was showing, there with strong empirical data, how complex networks of the human cerebellum and even the cortex operate entirely unconsciously. During the attentional blink, for instance, word meanings can be accessed nonconsciously, a feat that necessarily involves differentiated and integrated networks of the left temporal lobe. Tononi's theory makes no contact with such observations yet.

"The theory," Koch writes, "has profound consequences that bear some resemblance to the prophetic ideas of Pierre Teilhard de Chardin." Evolution implies a progressive amplification of global consciousness, with computers and the Internet as its most recent avatars. Openly confessing his recent familial turmoil and his loss of Christian faith, Koch finds solace in this view of life. He also admits that his long-time mentor and collaborator on the mind-body problem, Francis Crick, would have cringed. An avid reader of Jacques Monod's *Chance and Necessity* (7), I too was stunned: Rare are contemporary biologists who confess such thoughts, and they are even rarer, I thought, among those who study consciousness.

With its fascinating glimpses into the budding science of consciousness and the intermixed frank autobiographical notes (qualms of conscience included), *Consciousness* offers a charming read. Behind the lines, however, lies a darker message: neuroscience obviously cuts deep into one's life. One is inescapably reminded of a famous psychology experiment (8) in which reading a passage of Francis Crick's *Astonishing Hypothesis* (9)

on the genetic and neuronal determinants of behavior (thus weakening beliefs in free will and responsibility) increased cheating behavior. Can neuroscience be reconciled with living a happy, meaningful, moral, and yet nondelusional life? I will confess that this question also occasionally keeps me lying awake at night. However, I cannot but think that Koch is, unfortunately, misguided and that Crick and Monod are, unfortunately,

right: In the eternal silence of neuronal spaces, our anguish probably goes unheeded. My own optimism consists of enjoying every single moment of consciousness while it lasts.

References

1. C. Koch, *The Quest for Consciousness: A Neurobiological Approach* (Roberts, Englewood, CO, 2004); reviewed in (10).
2. G. Kreiman, I. Fried, C. Koch, *Proc. Natl. Acad. Sci. U.S.A.* **99**, 8378 (2002).
3. S. Dehaene, J. P. Changeux, *Neuron* **70**, 200 (2011).
4. A. M. Owen et al., *Science* **313**, 1402 (2006).
5. C. Koch, R. C. Reid, *Nature* **483**, 397 (2012).
6. G. Tononi, *Biol. Bull.* **215**, 216 (2008).
7. J. Monod, *Chance and Necessity: An Essay of the Natural Philosophy of Contemporary Biology*, A. Wainhouse, Transl. (Knopf, New York, 1971).
8. K. D. Vohs, J. W. Schooler, *Psychol. Sci.* **19**, 49 (2008).
9. F. Crick, *The Astonishing Hypothesis: The Scientific Search for the Soul* (Scribner, New York, 1994).
10. P. Haggard, *Science* **304**, 52 (2004).

10.1126/science.1222480

PSYCHOLOGY

Facilitating "A-ha!" Moments

Anna Vlasits

Creativity is an ill-defined skill that almost everybody wants. How can we attain it? Although I don't have the answer to this question, reading Jonah Lehrer's *Imagine* might lead one to some possibilities.

Full of suggestions and anecdotes, the book reads like a creativity self-help guide pumped up with the latest psychology and business research. In one chapter, Lehrer (a science writer) recounts how Scotch tape was invented. In another, he describes how psychologists discovered that uncritical brainstorming reduces creative output. Lehrer emphasizes that there are actually many different kinds of creativity, including right-brain creativity (implicated in "a-ha!" moments of

insight), left-frontal-cortex creativity (controlling highly focused, sustained creative output), and "innovative" creativity (as in cutting-edge businesses such as 3M, Pixar, and Google as well as groups of artists making Broadway musicals).

The reviewer is at the Helen Wills Neuroscience Institute, University of California, Berkeley, CA 94720, USA. E-mail: avlasits@berkeley.edu

Although the term "creativity" remains ill-defined throughout the book, by cutting the topic up into little pieces Lehrer hopes to get to the bottom of how humans become creative. *Imagine* is addictive, probably because the book contains information about our behavior that all of us have observed. I too work in coffee shops to get my imagination flowing; have insights while taking showers; and live in a city, where creative output is at its highest. Even more enticing are all of the little tricks that Lehrer pulls from psychology research on creativity. For instance, putting bathrooms in a space that forces people with different expertise to interact increases a company's creative output. Lehrer argues that anyone can be creative. It doesn't matter how drab you're feeling today or whether you have skills or training. Surround yourself with environmental conditions conducive to creativity, and you can produce something great.

The book aims to stimulate people to be as creative as possible. In fact, Lehrer holds that we should change our education system to emphasize teaching children to be creative. This raises the question of what we really get out of being more creative as a community. The two main outputs of creativity that Lehrer describes are technological innovations (read patents and therefore money) and art (read entertainment). It appears that he thinks creativity results in making either something that can be sold to people or something that will entertain them—or both.

There seems something sinister about reducing creativity to a checklist of to-dos and reducing the goals of our creative output to wealth and art. Whereas Lehrer acknowledges that "the creative process will never be easy, no matter how much we know about neurons and cities and Shakespeare," he does not address the important issue of what we should do with our creativity. Imagination can be used to invent a new way to build better solar panels or to cheat people out of money. Describing ways to direct human creativity toward good ends would certainly constitute a creative book.

That said, Lehrer smoothly and engagingly blends scientific findings with stories about creative breakthroughs. *Imagine* is just plain fun to read, and the author's neat prose dishes out valuable information. While writing this review, I couldn't help but match my creativity-related behaviors to his descriptions, and I consciously referred to the book for tips to make the process easier. I don't know whether doing so improved the results, but it certainly got my imagination going.

10.1126/science.1224275

Imagine How Creativity Works

by Jonah Lehrer

Houghton Mifflin Harcourt,
Boston, 2012. 299 pp. \$26.
ISBN 9780547386072.
Canongate, London. £18.99.
ISBN 9781847677860.