NEUROSCIENCE

Neural Communication Breaks Down As Consciousness Fades and Sleep Sets In

By using magnetic pulses to stimulate the brains of waking and sleeping volunteers, scientists may have gained an important insight into the age-old mystery of why consciousness fades as we nod off to sleep. In a report on page 2228, a research group at the University of Wisconsin (UW), Madison, concludes that as sleep sets in, communication between different parts of the cerebral cortex breaks down. Such communication is a likely prerequisite for consciousness, the team argues.

Some, but not all, neuroscientists find the team's evidence compelling. The research "definitely tells us something about sleep and may have important implications for understanding the neural correlates of consciousness," says Christof Koch, a cognitive neuroscientist at the California Institute of Technology in Pasadena.

Early neuroscientists assumed that consciousness wanes during sleep because the cerebral cortex simply shuts down. "In the last century, we had three Nobel Prize winners who thought that the cerebral cortex is completely inhibited during sleep," says Mircea Steriade, a neuroscientist who studies sleep at Laval University in Quebec, Canada. Electroencephalography (EEG) and other methods have since ruled out that explanation, showing that the electrical chatter and metabolism of neurons in the cortex continues unabated during sleep. That left neuroscientists puzzling over why consciousness fades when the brain is still active.

Giulio Tononi of UW has spent years developing a theory that the essence of consciousness is the integration of information. Communication between different regions of cortex might be one sign of this integration—and of consciousness, Tononi says. To test that idea, he and his team recorded electrical activity in the brains of six sleepy volunteers using high-density EEG. Before the subjects nodded off, the researchers stimulated a small patch of right frontal cortex with transcranial magnetic stimulation (TMS), a noninvasive method that uses magnetic pulses to induce an electrical current inside the head. The ▶

Drifting off. Magnetically stimulating the brains of sleeping volunteers may provide clues about the nature of consciousness.

CRYPTOGRAPHY

Simple Noise May Stymie Spies Without Quantum Weirdness

With the grand ambition of sending unbreakable coded messages, some physicists are using exotic tools—streams of individual photons and quantum mechanics—to shut out prying eyes. But a wire and a few resistors may convey a message as securely, says a physicist who has devised a simple and—he claims—uncrackable scheme. The idea shows that "classical" methods might compete with budding "quantum cryptography," others say. "I believe in beautiful and simple ideas, and this is one of them," says János Bergou, a theorist at Hunter College of the City University of New York.

Stealth technology. A simple wire and resistors may send data securely.

Take the hypothetical secret sharers, Alice and Bob: They transform a message into binary numbers and use a numerical "key"—a secret string of random 0's and 1's—to scramble and unscramble it. Quantum cryptography allows them to pass the key under the nose of an eavesdropper, Eve, because she cannot measure the condition of a particle without affecting it. So if Alice and Bob encode the key in individual photons, Eve cannot read it without revealing herself.

But Alice and Bob might do just as well by measuring the electrical noise on the ends of a wire, says Laszlo Kish of Texas A&M University in College Station. In Kish's scheme, Alice and Bob have two resistors each, one with a big resistance and one with a small resistance. Each randomly connects one resistor or the other between his or her end of the wire and ground and measures the voltage between the wire and ground.

On average, that voltage is zero. But electrons in the resistors jiggle about with thermal energy, so the voltage fluctuates, and the size of the fluctuations, or "Johnson noise," depends on the resistances Alice and Bob choose. If both use the large resistance, the fluctuations will be big. If both use the small resistance, they will be small. And if one uses large and the other uses small, the noise takes an intermediate value.

Eve can measure the fluctuations, too. But when the noise is at its intermediate level, she cannot tell whether Alice or Bob has chosen the large resistance unless she injects a current, which will reveal her presence, as Kish describes in a paper posted on the Web site www.arxiv.org and submitted to the journal *Physics Letters A*. So Alice and Bob can use the large-small pairs to generate the key.

Making the scheme work over long distances may not be easy, says Weston Tew, a physicist at the National Institute of Standards and Technology in Gaithersburg, Maryland. And Bergou notes that if the wire itself has a sizable resistance, then the fluctuations should be slightly larger on the end with the large resistance, a fact Eve might exploit if she spies on both ends at once. Still, today's quantum technologies only approximate the uncrackable ideals, and Kish's idea suggests that simpler schemes might match their performance, says Julio Gea-Banacloche, a theorist at the University of Arkansas in Fayetteville. "The more I think about it," he says, "the more I think that within limits it's workable."

–ADRIAN CHO

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EEG record revealed how the neural activity triggered by TMS spread from the site of stimulation to other parts of the brain. The team repeated the experiment once the subjects had entered non–rapid eye movement (non-REM) sleep. Noise-canceling earphones ensured that subjects couldn't detect the sound of the TMS magnet.

When the subjects were awake, TMS elicited waves of neural activity that spread through neighboring areas of the right frontal and parietal cortex and to corresponding regions on the left side of the brain. During non-REM sleep, the same TMS stimulus only elicited neural activity at the site of stimulation.

Tononi says the findings suggest that different areas of cortex do indeed stop talking to each other during non-REM sleep—a stage of sleep in which people often report little or no conscious experience on waking. An important follow-up, he says, will be to repeat the experiments during late-night REM sleep, when people report consciouslike experiences in the form of dreams. "We would predict a pattern which is much more similar to wakefulness," he says.

Linking cortical connectivity to consciousness makes sense, says Rodolfo Llinas, a neuroscientist at New York University. A key feature of consciousness is the ability to integrate many aspects of an experience into a single perception—combining red petals, rosy scent, and prickly thorns into the perception of a rose, for example. "To make an object in your head, to make one single cognitive event, you have to bind the activity of many cortical areas," Llinas says.

But not everyone accepts Tononi's conclusions. The experiments are "very elegant and pretty," but their relevance to understanding consciousness is questionable, says Robert Stickgold, a neuroscientist who studies sleep at Harvard Medical School in Boston, Massachusetts. "There are many, many differences in brain chemistry and physiology … between wakefulness, non-REM sleep, and REM sleep," including differences in neurotransmitter and hormone levels and patterns of neural activity, Stickgold says. The change in cortical communication is yet another such difference, he agrees, but there's no convincing evidence that it's the key to fading consciousness. –GREG MILLER

HIGH-RISK RESEARCH

Six Women Among 13 NIH 'Pioneers'

The résumé of evolutionary psychologist Leda Cosmides of the University of California, Santa Barbara, proudly lists that she was a finalist in last year's inaugural competition for the 5-year, $2.5 million Pioneer Award from the National Institutes of Health (NIH), even though she didn't win a penny. In fact, there were no women among the nine winners, an omission that triggered complaints of gender bias (*Science*, 22 October 2004, p. 595).

What a difference a year makes. This week, Cosmides, 48, and five other women join an elite group of 13 scientists chosen for the 2005 Pioneer Awards,* which NIH Director Elias Zerhouni says are designed for "exceptionally creative scientists taking innovative approaches to major challenges in biomedical research." The dramatic shift in gender composition was not a goal of the selection process for the second competition, says Jeremy Berg, director of the National Institute of General Medical Sciences, who oversaw the competition. But, he says, NIH did make a very deliberate attempt to level the playing field.

Award winners. Leda Cosmides and Peter Harbury are part of a baker's dozen whose proposals wowed NIH judges.

CREDITS (LEFT TO RIGHT): MIRANDA SAVANI; P. HARBURY

"Women, underrepresented minorities, and early-career scientists were especially encouraged to apply," Berg says. Accepting only self-nominations (rather than institutional submissions) may also have helped remove any subtle advantages, he adds. He says NIH spent more time schooling its reviewers, who last year were overwhelmingly male, on the importance of looking for the best people with the most exciting ideas. Having fewer applications this year—some 840 compared with 1300 in 2004—also made the three-tiered review process go more smoothly, he notes. The result was not only a better gender balance but also a younger cohort represented by 35-year-old Nathan Wolfe, a tenure-track molecular epidemiologist at Johns Hopkins University in Baltimore, Maryland, who spends the majority of his time working with hunters at a Cameroon field station in search of zoonotic diseases in the early stages of adapting to humans.

For Cosmides, the award represents further affirmation for a field that she and her husband, John Tooby of Harvard University, helped establish in the early 1980s. "Those were tough years," she recalls. "Something like this at the beginning of our work would have been a godsend. I can't say enough about what NIH is trying to do [with this award] to encourage novel work across disciplinary boundaries."

Stanford University neuroscientist Ben Barres, a vocal critic of last year's awards, says he was "deeply impressed by how NIH revamped the process this year." As it happens, he also chaired the final round of face-to-face, 1-hour interviews on the NIH campus, at which he says "gender or race issues" never surfaced. But the quality of the science being proposed blew him away, he adds.

Pehr Harbury worried that he'd blown his chances when his laptop swallowed his PowerPoint presentation during a cab ride to NIH. But the 40-year-old Stanford biochemist, who received tenure just last year, needn't have worried. Not only did his description of applying computer-generated small molecules to design a vast new class of potential drugs impress the NIH judges, but 1 day after winning a Pioneer Award, Harbury learned that he had also been awarded a so-called genius grant—and $500,000 with no strings attached—from the John T. and Catherine B. MacArthur Foundation.

"I feel a little guilty," he confessed. "I've been scraping along [NIH had rejected his first six single-investigator proposals, and he currently has one R01 for his six-person lab], and the MacArthur prize is for people having trouble getting funding. And now I have more money than I ever imagined."

–JEFFREY MERVIS

* nihroadmap.nih.gov/pioneer

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