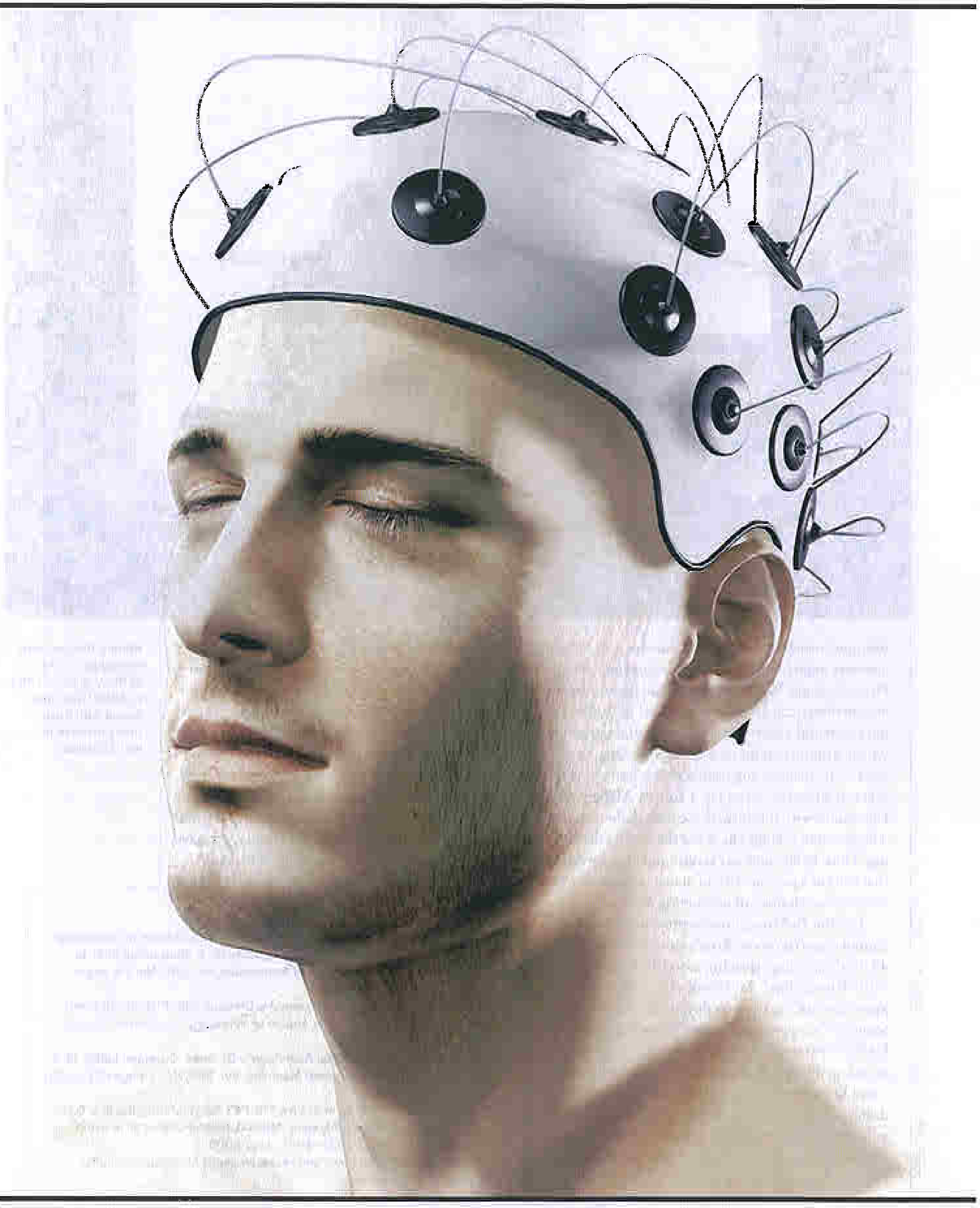
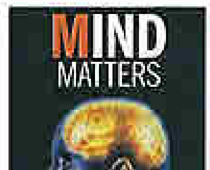


Meditation on Demand

New research reveals the cell mechanisms underlying a meditative state

By Peter B. Reiner



This article was adapted from Mind Matters, www.ScientificAmerican.com/MindMatters, a column edited by Gareth Cook, a Pulitzer Prize–winning journalist at the *Boston Globe*, and Jonah Lehrer, the science writer behind the blog The Frontal Cortex, http://scienceblogs.com/cortex

In the fall of 2005 the Dalai Lama delivered a lecture at the annual meeting of the Society for Neuroscience in Washington, D.C., highlighting the areas of convergence between neuroscience and Buddhist thought about the mind. He took the opportunity to remind the audience that not only is he a Buddhist monk but that he is also an enthusiastic proponent of modern technology. [For more on the Dalai Lama's lecture, see "Meditations on the Brain," by R. Douglas Fields; SCIENTIFIC AMERICAN MIND, February/March 2006.]

Elaborating, the spiritual leader of Tibet explained to the audience of scientists that although he meditates for four hours every morning, it is hard work. He divulged that if neuroscientists could find a way to put electrodes in his brain and create the same outcome he gets from meditating, he would be an eager volunteer. Now a set of experiments from researchers at the Massachusetts Institute of Technology and Stanford University moves us a step closer to making his wish a reality. The neuroscientists managed to induce in mice a brain-wave pattern associated with meditation—answering a long-standing question about how this pattern is generated and theoretically laying the groundwork for a cognitive-enhancement technology that could mimic meditation's effects.

To better understand how the new work relates to meditation, it helps to review some earlier studies. The Dalai Lama's keen interest in neuroscience has been reciprocated by at least some members of the neuroscience community, who reason that studying people who meditate might lead to novel

FAST FACTS

Rhythm of Serenity

1» Regular deep meditation changes the brain in positive ways. This type of meditation seems to be associated with gamma waves, the electromagnetic rhythm of neurons firing very rapidly in harmony.

2» Neuroscientists have pinpointed the cells responsible for producing these gamma rhythms and demonstrated a technology that can induce the brain-wave pattern in mice.

3» In the future it might be possible to use this technology to reproduce some of the beneficial effects of meditation.

AGE FOTOSTOCK

insights about the workings of the human brain.

From the perspective of neuroscience, meditation can be characterized as a series of mental exercises by which a person strengthens control over the workings of his or her own brain. The simplest of these practices is focused attention, during which one concentrates on a single object or experience—say, one's breathing. Many studies have described how the ability of long-term meditators to focus and attend to tasks differs from people who are new to the practice. For instance, expert meditators perform better on rapid-fire visual tests because they avoid the common pitfall known as attentional blink, which causes most people to miss a second target because they focus too long on the first. [For more about the neuroscience of meditation, see "Searching for God in the Brain," by David Biello; SCIENTIFIC AMERICAN MIND, October/November 2007.]

Thinking about Thinking

But focused-attention meditation is fairly basic compared with the kind of contemplation conducted by experienced Buddhists. Called open-monitoring meditation, this advanced method is, in many ways, a form of metacognition—the objective is not to focus one's attention but rather to use one's brain to monitor the universe of mental experience without directing attention to any one task. Psychologist Richard Davidson led a seminal study of open-monitoring meditation at his laboratory at the University of Wisconsin–Madison.

Using electroencephalographic (EEG) recordings, Davidson and his colleagues compared long-term Buddhist practitioners with students who had been introduced to the principles of meditation a week before the study and were instructed to practice an hour a day. The findings, reported in *Proceedings of the National Academy of Sciences USA* in 2004, were unexpected: the long-term meditators' brain waves (the electrical oscillations indicative of neural activity) were in sync at unusually high speed. Brain waves, which signify groups of neurons firing in relative harmony, occur at different speeds—slow delta waves happen only in dreamless sleep, for example, and rapid beta waves occur during concentration and cognition. Gamma waves are the fastest of the bunch, and in normal people they happen only in very short bursts during REM sleep and, rarely, waking cognition. The Davidson study was remarkable in that it showed that long-term meditators are able to produce sustained gamma activity in a manner that had never been previously observed in a human being. As such, sustained gamma activity emerged as a proxy for at least some aspects of the meditative state.

If sustained gamma rhythm is a hallmark of meditation, could we achieve "meditation on demand" for the Dalai Lama by inducing gamma waves in the brain? Perhaps—but first researchers must tease out how exactly gamma rhythm is produced in the brain. This mechanism is precisely what the new studies defined and replicated.

In two new studies published in *Nature* in June, the laboratories of Christopher I. Moore and Li-Huei Tsai at M.I.T. and Karl Deisseroth at Stanford tested and confirmed the hypothesis that gamma rhythm results from the activation of fast-spiking interneurons, so named because they fire at a higher than normal rate and have short, local connections within the cerebral cortex, the outer layer of gray matter responsible for higher cognition. The experimenters utilized optogenetics—combining optical (light-based) and genetic techniques to investigate the brains of living animals. They developed viruses that infected only the fast-spiking interneurons of either the prefrontal cortex or the barrel cortex (the area that processes sensory input from a rodent's whiskers) in mice.

The virus delivered an engineered gene that made the target cells sensitive to light. Then the researchers inserted fine optical fibers into the relevant region of the mouse cortex, allowing light to be delivered to the infected neurons and thereby activating only the fast-spiking interneurons. In essence, this procedure allowed them to switch particular brain cells on and off with exquisite temporal and spatial control. In both experiments, selectively

(The long-term meditators' brain waves were in sync at **unusually high speed.**)

(The Author)

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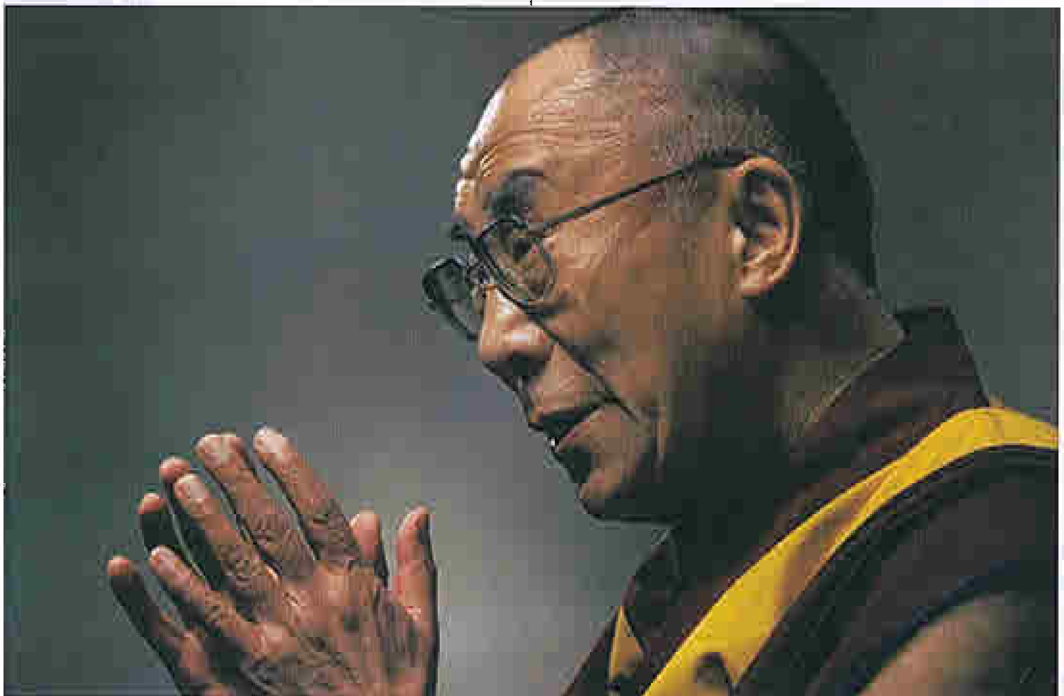

AMIT SHAB *laif/Redux Pictures*

The Dalai Lama urged neuroscientists to find a way to use technology to induce in the brain the benefits of arduous meditation. A new study in mice may point the way to such technology.

stimulating the fast-spiking interneurons evoked gamma oscillations, thereby confirming the hypothesis that these neurons drive the gamma rhythm.

Riding the Waves

The sustained gamma activity evoked in these mice is, of course, highly reminiscent of the type of electrical activity recorded from the long-time meditators practicing the elusive phenomenon of open-monitoring meditation. That being said, sustained gamma activity is not identical to meditation—so this experiment alone (despite the elegant methods used) clearly does not satisfy the Dalai Lama's challenge to the neuroscience community to develop a technological replacement for the many hours spent immersed in contemplative thought.

Given the growing body of evidence that suggests that even short-term meditation improves measures of attention, however, these new experiments provide an interesting twist to the growing field of cognitive enhancement. If gamma-wave synchrony is indeed responsible for some of meditation's beneficial effects on the brain, inducing such rhythms artificially might result in similarly desirable outcomes. In addition, abnormal gamma synchronization is a hallmark of disorders such as autism and schizophrenia, and it may contribute to altered cognition in these and other mental illnesses. Thus, developing a technology that could correct the gamma rhythm could be invaluable for clinical treatment.

How long will it be before a new version of this technology is available for human consumption? It is hard to imagine anyone but the most ardently progressive technophile signing up to have genetically engineered viruses and optical probes inserted into his or her brain. But it is worth remembering that both deep-brain stimulation, whereby implanted electrodes act as a kind of pacemaker in the brain, and transcranial magnetic stimulation, in which powerful magnetic fields are transmitted through the skull to affect brain activity, are rapidly moving from the lab to the clinic. Both these techniques represent relatively crude forms of brain stimulation.

Still, the emerging field of optogenetics is advancing very quickly. One recent paper in *Neuron* demonstrated that neurons can be infected and optical fibers implanted safely in nonhuman primates. At the very least, it is safe to say that the prospect of using advanced technology to mimic at least some of the brain activity present during meditation states has moved from the realm of science fiction to that of scientific possibility. M

(Further Reading)

- **Driving Fast-Spiking Cells Induces Gamma Rhythm and Controls Sensory Responses.** Jessica A. Cardin, Marie Carlén, Konstantinos Meletis, Ulf Knoblich, Feng Zhang, Karl Deisseroth, Li-Huei Tsai and Christopher I. Moore in *Nature*, Vol. 459, pages 663–667; June 4, 2009.
- **Parvalbumin Neurons and Gamma Rhythms Enhance Cortical Circuit Performance.** Vikaas S. Sohal, Feng Zhang, Ofer Yizhar and Karl Deisseroth in *Nature*, ibid., pages 698–702; June 4, 2009.

