THE SECRET TO RAISING SMART KIDS (page 36)

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December 2007/January 2008 www.SciAmMind.com

Empathetic Mice and **Animal Emotions**
page 28

BORED?

Find your focus—and you could change your life

Why Men Dominate in Science and Math

Psychedelic Meds Could Ease Troubled Minds

A Look Inside the **Terrorist Psyche**

PLUS:
Phantom Limbs and Amputee Envy

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Scientific American Mind
415 Madison Avenue
New York NY 10017-1111
212-451-8200
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COVER IMAGE BY AARON GOODMAN

Beat the Blahs

I've never been good at waiting around for something to do. If work slackens slightly, I volunteer for new projects that I will find challenging—and the way I race down the hall from one task to the next is the subject of a lot of good-natured office humor. My shoulder bag is always stuffed with reading material, to ward off idle moments during the train ride home. Truth is, I just really, really hate being bored.

One way I recently have staved off dullness is by reading Anna Gosline's fascinating account of the complex psychological underpinnings of what she calls "this most tedious of human emotions." In her feature article "Bored?" she explains how multifaceted those ho-hum moments actually are, influenced by levels of attention and awareness, emotional factors, adeptness at identifying one's own feelings, and the nature of the matters at hand. Boredom can drive some people to achieve—but those who easily experience ennui are more prone to suffer chronic depression or drug addiction. Getting at the roots of boredom could help prevent and treat these ailments. The story begins on page 20.

Surely the least boring decade in the past century was the psychedelic sixties, when so much of pop culture seemingly came under a hallucinogenic influence. Now, after a long research hiatus, those drugs are back in the labs. Scientists are probing the very real value of LSD and other mind-blowing drugs to ease a variety of difficult-to-treat mental illnesses, including depression, post-traumatic stress disorder, obsessive-compulsive disorder, and drug or alcohol dependency. Check out "Psychedelic Healing?" by David Jay Brown, on page 66.

Medicines are not the only way we improve our mental health, of course. Habits, behavior and helpful feedback are also important. That is why, advises psychologist Carol S. Dweck in "How to Raise a Smart Child," we need to be careful about how we praise our children. Yes, you read that right. Encouragement is valuable—but it has to be the right sort. Curious? Turn to page 36. We hope the article will make you feel wiser, too.

Mariette DiChristina
Executive Editor
editors@SciAmMind.com

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LEADERS AND DICTATORS

I read with great interest "The New Psychology of Leadership," by Stephen D. Reicher, S. Alexander Haslam and Michael J. Platow. In light of my own experience, the article does capture the salient points of good leadership, but I feel it has not given proper weight to the idea of achievement.

Achievement is satisfaction (or accolades) received by a group for supporting its leader. In short, achievement acts as feedback that demonstrates to the group that its faith in supporting the leader's vision has not been in vain. Benito Mussolini made the trains run on time; the people who supported his totalitarian view were recipients of a transportation system they could count on. Without this feedback, the dictator's appeal would have been lost.

Achievement is a necessary element in maintaining a group's voluntary submission to a leader's authority. Without this feedback, leadership authority would have to be enforced through administrative dictates.

Ehor Mazurok
Edmonton, Alberta

Did your article on leadership actually name George W. Bush as an example of a modern leader? This otherwise well-written article should have identified him as an example of a nonleader based on the facts presented. Bush's popularity has continued to drop, which would imply that a one-time good speech and a few photo opportunities were examples of charisma that could not sustain the people in the long run, and thus he is not a knowledgeable member of the group. I read and reread this article, and his placement in it seemed forced and out of place. If you are looking for American leaders who fit the paradigm of this article, there are many from which to choose, including Thomas Jefferson, Harry S. Truman and John F. Kennedy.

Bob Spellman
via e-mail

THE EDITORS REPLY: *The example showed Bush's leadership in a particular context at a particular time. Even if a person fails as a leader in some respects, he or she may nonetheless display some exemplary leadership qualities.*

MIRROR-INDUCED MIGRAINE

In "It's All Done with Mirrors" [Illusions], Vilayanur S. Ramachandran and Diane Rogers-Ramachandran describe a simple experiment that explores the effects of bringing the visual and motor senses into conflict by using a mirror to distort the visual representation of one's left and right hands.

My wife and I decided to perform the described experiment. When I viewed my hands in the mirror, I experienced the "jolt of surprise" that the authors predicted, but my wife's reaction was totally unexpected. The instant she looked into the mirror she recoiled. She complained of dizziness, and within seconds she complained of a headache and then a pain in her left eye. These symptoms are exactly the same as those she experiences at the onset of her migraine headaches, which she has suffered from for more than 35 years. Could it be that my wife and I uncovered an unknown cause—sensory confusion—of migraines?

Rodger A. Sanders
McMinnville, Tenn.

COMMON SYMPTOMS

While I was reading Thomas Grueter's feature on prosopagnosia, "Forgetting Faces," I began to wonder if children who have this "perceptual quirk" tend to be diagnosed as having autism. When a child is suspected of being autistic, parents and teachers often comment that he or she does not use eye contact or know the names of classmates. Is it possible that the snowball effect of prosopagnosia generates autisticlike behavior? Should prosopagnosia have a place on the autism spectrum?

Roseann Rash
Boston

GRUETER REPLIES: *The relation between prosopagnosia and autism is an important issue because, as Rash suggests, the disorders can share symptoms. Research indicates that prosopagnosia is a visual-processing deficit, however, not a pervasive developmental disorder, and therefore it does not belong on the autism spectrum.*

One of the core disabilities in autism spectrum disorder (ASD) seems to be the lack of a "theory of mind." Because of a defect in their mirror neurons, people who have autism are severely impaired when it comes to judging other people's moods or feelings. In addition, autistic people's brains have a harder time filtering input, so these individuals suffer from constant sensory overstimulation.

None of these problems arise in children with prosopagnosia. Autistic children actively avoid looking at people's eyes, but prosopagnosic children simply forget about it and can be trained to keep gaze contact in conversations. Additionally, their empathy for other people is unimpaired and sometimes even better than in other children. And whereas children with ASD acquire language quite late, children with prosopagnosia tend to talk early.

Both disorders, however, share a striking symptom: afflicted children do not look into the face of people they talk to. This lack of eye contact may lead people to incorrectly suspect ASD in children with prosopagnosia simply because congenital prosopagnosia is still unknown to most people. In fact, the prevalence of congenital prosopagnosia is probably about 10 times as high as that of ASD. Therefore, some prosopagnosic children may indeed be wrongly diagnosed with ASD.

NO GUNS, NO SHOOTINGS

Frank J. Robertz is correct in "Deadly Dreams" when he advises that teenage malignant thoughts should be analyzed as a means of preempting and stopping the acting out of these ideas. This proposal is a sound psychological approach given that such "intrusive thoughts" are part of normal cognition, but psychological tactics are limited by the social context in which these child assassins are nurtured. As long as the right to own many semiautomatic weapons is socially acceptable, people with the intent to play out violent fantasies will have the opportunity to do so. Disarming the general population of all firearms will be the only real means of reducing this type of mass homicide.

What is the most effective way to prevent teenagers from acting out their violent fantasies?

DANIEL MACKIE Getty Images

Intrusive thoughts are normal and will forever be so. When these thoughts become malignant, weapons of mass murder should not be readily available to young or old.

Andrew Jones
via e-mail

DRINK UP AND DROP OUT

In "Why We Quit," Yvonne Raley claims that student comfort, faculty support, and study habits are factors in whether a college student fails. I agree, but I also believe that drugs and alcohol are an even bigger hurdle. Not only does alcohol abuse affect the brain, it has become an accepted part of college culture. I would like to see statistics for drop-out rates based on the persuasions of alcohol and a party lifestyle.

Grace Poll
St. Ursula Academy
Toledo, Ohio

RALEY REPLIES: *As far as I know, there are no national studies directly correlating alcohol abuse on campus and student drop-out rates. But studies on the drinking habits of college students indicate that heavy drinking is most common among first-year students. Dropping out is also most likely in the first year, so the association is definitely worth exploring. I think we can safely say that alcohol (and also drugs) can have a negative impact on student performance and thus retention, but until more research is done it is hard to tell exactly what the nature of that correlation may be.*

Many college campuses have tried to face this problem head on and have started initiatives to prevent alcohol abuse. At Felician College, where I am an assistant professor, a counselor attends every freshman class in the first semester to do a workshop. A number of other colleges do the same.

Head Lines

JOHN RITTER

>> COGNITION

Left Brains vs. Right Brains

Political ideology is tied to how the brain manages conflict

People who describe themselves as being politically liberal can better suppress a habitual response when faced with situations in which that response is incorrect, according to research that used a simple cognitive test to compare liberal and conservative thinkers. Tasks that require such "conflict monitoring" also triggered more activity in the liberals' anterior cingulate cortex, a brain region geared to detect and respond to conflicting information.

Past research has shown that liberals and conservatives exhibit differing cognitive styles, with liberals being more tolerant of ambiguity and conservatives preferring more structure. The new paper "is exciting because it suggests a specific mechanism" for that pattern, comments psychologist Wil Cunningham of Ohio State University, who was not involved with the study. In the experiment, subjects saw a series of letters flash quickly on a screen and were told to press a button when they saw M, but not W. Because M appeared about 80 percent of the time, hitting the button became a reflex—and the more liberal-minded volunteers were better able to avoid the knee-jerk reaction.

The study's lead author, psychologist David Amodio of New York University, emphasizes that the findings do not mean that political views are predetermined. "There are a lot of steps between conflict monitoring and political ideology, and we don't know what those steps are," he says. Although the neurocognitive process his group measured is so basic that it is most likely in place in early childhood, he notes that "the whole brain is very malleable." Social relationships and other environmental factors also shape one's political leanings.

—Siri Carpenter

Persisting toward an unreachable goal may raise a person's risk for chronic illness.

>> HEALTH

Who Said Quitters Never Win?

If at first you don't succeed, quit—for your future health

Some people stop at nothing to get what they want, persisting in the face of continual hardship. Often seen as a sign of strength, this behavior may also be indicative of future illness, according to a new study.

Psychologists asked 90 adolescent girls about their tendency to hold on to unattainable goals. Over the next year, they found that the girls who said they never gave up had more quickly increasing blood levels of C-reactive protein (CRP) as compared with the girls who were moderately good at letting go. High levels of CRP often precede the development of heart disease, cancer and diabetes. And although CRP levels are expected to rise over time, the faster rate of increase in people who persevere relentlessly could give them an elevated risk for illness later in life.

The researchers are not sure exactly how the rising CRP levels translate into future health problems, but they are confident that further investigation will tease out the connection. The more difficult part is figuring out when to give up on a goal, says study author Gregory Miller, a psychologist at the University of British Columbia. "It's like that Kenny Rogers song: you've got to know when to fold them," he says. "But it's really hard to know."

—Melinda Wenner

>> NEUROSCIENCE

One Size Fits All

Mouse brains may contain both male and female wiring

Behavior is controlled by the brain, so the brains of male mice must differ from those of female mice—right? Not necessarily, say biologists at Harvard University who have created female mice that exhibit classic male sexual behavior. "Mice have an organ in their nose called the vomeronasal organ, or VNO, that together with the brain detects the pheromones that male and female mice secrete," Catherine Dulac explains. "These pheromones control mating, aggression and gender identification." When Dulac and her collaborators disabled the females' VNO through surgery or genetic mutations, they were surprised to see the mice start behaving like males. "The mutant females were aggressive toward strange males, sniffed at their genitals and mounted them," Dulac says. The mice remained functionally female, however, and in fact mated and gave birth. Then came the second surprise: the mutant mothers quickly abandoned their nests and young and went off to explore their cages—much as males would. The experiment, Dulac adds, implies that the neuronal circuits for "male" behavior exist in the brains of female mice and that the animals' VNO, by sensing pheromones, controls which sexual behavior repertoire is expressed.

Although humans and other higher primates lack a functional VNO, the researchers think that different sensory controls (such as visual or auditory cues) may be involved in activating sexual behavior in these species. [*For more about pheromones in humans, see "Sex and the Secret Nerve," by R. Douglas Fields; Scientific American Mind, February/March 2007.*] The next step, Dulac says, will be to analyze male mice without a functioning VNO to see if they display femalelike behaviors.

—Jonathan Beard

GABE PALMER *Corbis (top)*; CORBIS *(bottom)*

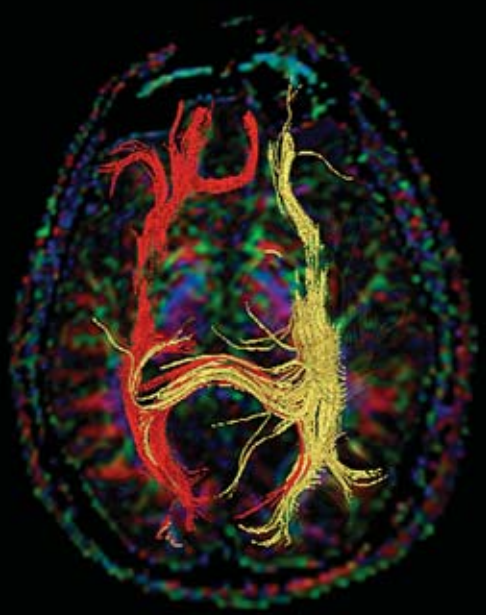
>> IMAGING

A New View

Internal connections become clear

Magnetic resonance imaging (MRI) has illuminated the functions of many structures in the brain, but until recently the physical connections between these structures were considered "MRI invisible." Not so anymore, as this picture illustrates: crisp outlines in red and yellow show white matter tracts running through and between the left and right hemispheres. This new MRI approach, called diffusion tensor imaging (DTI), tracks water diffusion along nerve fibers, exposing the microarchitecture of the brain. DTI promises not only to open up a new avenue of research into the brain's wiring but also to give doctors a powerful diagnostic tool. When a white matter tract is damaged by a neurodegenerative disease, its cellular membranes no longer restrict water flow, and diffusion becomes more random. DTI can detect such degeneration, as a team at the University of Alberta demonstrated in patients with amyotrophic lateral sclerosis, or Lou Gehrig's disease.

—Amelia Thomas



SURESH K. MUKHERJI *University of Michigan Health System (top)*; DAVE KING *Getty Images (bottom)*

>> BEHAVIOR

Monkey See, Monkey Ignore

Primates can delay gratification to earn a bigger prize

Playing with toys helped chimps distract themselves from a growing pile of candy.

When a person's behavior is out of control, people might say he is "going ape." It appears, however, that our closest relatives can behave themselves better than we thought. New research in chimpanzees and monkeys could reveal clues about how self-control originated in humans.

Even children know that resisting instant gratification can lead to greater rewards. Past research showed that to cope with such delays kids can distract themselves by playing. Now psychologists Theodore Evans and Michael Beran of Georgia State University find that chimpanzees can also employ diversions to control themselves.

The scientists tested chimps with a candy dispenser that delivered a treat every 30 seconds. As soon as the apes reached for the accrued sweets, no more candy came—so if the chimps exercised restraint, they earned a greater reward. Sometimes the chimpanzees were given toys, such as magazines or toothbrushes. Evans and Beran found that the apes could resist temptation about 50 percent longer when they could amuse themselves with playthings, racking up 17 candies on average with toys and only 11 without toys.

Evans's other work has revealed self-control among more distantly related primates as well. For instance, tufted capuchin monkeys can show enough restraint to use celery stalks and pretzel rods to scrape peanut butter out of a cylinder, rather than devouring the edible sticks immediately.

The evolution of more sophisticated degrees of self-control might have been key to our ancestors' developing time- and labor-intensive faculties such as tool making, Evans says. Further comparisons between humans and other primates could help us understand when and how our self-control became as complex as it did.

—Charles Q. Choi

>> MEDICINE

Smoking Away Schizophrenia?

Nicotinelike drugs show promise for alleviating cognitive impairment

Schizophrenia is famous for its symptoms of hallucinations and delusions, but sufferers also face debilitating cognitive impairment—and standard treatments with antipsychotic medications do little to compensate for intellectual loss. Seeking improved mental clarity, many patients turn to a seemingly mundane source: cigarettes. The extraordinarily high incidence of smoking in individuals with schizophrenia—about 85 percent of patients smoke compared with some 20 percent of the general population—has spurred researchers to investigate the therapeutic effects of nicotine in the diseased brain.

Every schizophrenia patient suffers some degree of deficit in memory, attention and thought organization, but no medication currently exists to treat these cognitive impairments. According to patients who smoke, cigarettes alleviate some of these symptoms, but research has found that the effect is short-lived and detrimental to overall health. The receptors to which nicotine binds in the brain quickly become desensitized, rendering smoking ultimately ineffective. And while the positive effects are disappearing, addiction is under way.

As an alternative, researchers are investigating newly derived chemical compounds that bind weakly to the brain's nicotine receptors. Many of these binding agents are being tested in people who have schizophrenia, Alzheimer's disease or attention-deficit hyperactivity disorder (ADHD). Although the mechanisms underlying nicotine's cognitive effects remain unclear, scientists think it might improve focus by enhancing the brain's ability to filter out unwanted external stimuli. Schizophrenia alters the chemical communication signals used by neurons, making it difficult for the brain to isolate a single process and devote conscious attention to it. Nicotine modifies these signaling processes and may help dampen extraneous neuronal activity.

Schizophrenia expert Carol Tamminga, professor of psychiatry at the University of Texas Southwestern Medical School, says, "Doctors like me hope that in five or 10 years we'll have medications for different symptom domains. It's unclear if we're going to get medications that target specific aspects of cognition, like an attention or memory enhancer specifically, or if we're going to get drugs that cross the board in a more global way." But for patients, any treatment would be a welcome relief. *—Lisa Conti*

Remedy from the Sea

The discovery by William Kem, professor of pharmacology at the University of Florida, of a tobaccolike toxin in an ocean-dwelling worm (*Paranemertes peregrina*) has led to a promising compound that mimics nicotine's effects in the brain. Dubbed GTS-21, the potential drug ingredient enhances cognition in healthy adults and patients with schizophrenia and is not addictive. *—L.C.*

BRIEFS

■ **A daily tipple** can boost memory, according to new research from the University of Auckland in New Zealand. Rats that consumed the equivalent of one or two beers a day showed marked improvement in remembering visual and emotional stimuli. The modest booze consumption strengthened communication between memory neurons. A heavy alcohol diet, however, took a toll on object recognition.

■ **Using carefully** placed cameras, scientists at Sweden's Karolinska Institute created an out-of-body experience in the lab. Volunteers sat with their back toward two video cameras and wore a special headset that displayed the cameras' output, mimicking their normal vision. When the researchers touched the subject's chest and at the same time performed a similar motion just below the camera's field of view, the volunteers suddenly felt like they were watching their body from behind. By studying this kind of sensory illusion, the researchers hope to gain insight into the nature of consciousness and the "first person" experience.

■ **Neuroscientists** at Weill Cornell Medical College discovered that timing is key to interpreting the complex electrical pattern produced by the brain. By detailing the neural code of cats as they viewed natural scenery, the researchers found that meaningful patterns of neuronal activity can be detected at intervals as brief as 10 milliseconds—a much shorter timescale than previously thought.

PEDRO COLL *age Fotostock (top)*; MARY JO ADAMS *WSU Beach Watchers (bottom)*

>> LANGUAGE

Understanding Baby Talk

New studies reveal the universal nature of the singsong way we talk to infants

Nearly everyone who bends over the crib of a baby bursts into bubbling, musical tones to try to get the infant's attention. This baby talk, or "motherese," is widely considered to be a universal feature of human language, but now scientists report that a similar phenomenon might exist in other species—a finding that could help explain baby talk's evolution.

Rhesus monkeys use special vocalizations called grunts and girneys when they are around infants, but most researchers had believed the monkeys were directing the sounds at the mothers holding the babies. Now University of Chicago biologists Dario Maestripieri and Jessica Whitham have shown in a careful observational study that the monkeys were aiming the soft, nasal sounds at the infants. The vocalizations, Maestripieri says, are probably intended to get the newborn's attention and facilitate social interactions among group members—some of the same functions baby talk is thought to serve in people.

This monkey version of baby talk lends support to the popular theory that motherese helps humans build connections with their infants by attracting and holding the babies' attention. Some researchers believe that the interest babies show in motherese could aid language development, and a few linguists take the idea a step further, suggesting that the extended vowels and exaggerated tones of motherese could teach infants basic grammar. Others contend, however, that the melodic sounds may have a simpler purpose—to facilitate comprehension.

This hypothesis is supported by another new study, which showed that motherese can convey meaning between people who do not speak the same language. Cognitive psychologist Greg Bryant of the University of California, Los Angeles, found that the Shuar people of South America, who do not speak or understand English, were able to get the gist of North American mothers' utterances 75 percent of the time when the women spoke as if they were addressing a newborn. This cross-cultural comprehension of motherese suggests that its basic characteristics appeared early in human history—and that it may have originated for the same socially beneficial reasons that led our monkey relatives to develop their own form of baby talk.

—Kat Leitzell

Monkeys, like humans, build connections with their infants by using special vocalizations.

PETER OXFORD *Minden Pictures (top)*; COLORBLIND IMAGES *Getty Images (bottom)*

>> LEARNING

Shoot First, Ace Geometry Later

Video gaming may eliminate the gender gap in spatial skills

Playing an action-packed video game nearly wipes out sex differences in a basic spatial thinking task, research reveals. In a study of college students, men were better than women at rapidly switching their attention among stimuli displayed on a computer screen, a common test of spatial ability. But after both sexes played the role of a World War II soldier in a video game for 10 hours over several weeks, women caught up to men on the spatial-attention task, as well as on an object-rotation test of more advanced spatial ability. Women's gains persisted when the volunteers were retested an average of five months later.

The study's lead author, University of Toronto psychologist Ian Spence, speculates that the video game practice may have caused "massive overexercising" of the brain's attentional system or even switched on previously inactive genes that underlie spatial cognition. Either way, he says, the results hold tantalizing potential for designing action-intensive video games that appeal to girls and women, perhaps eventually boosting women's participation in fields such as mathematics and engineering, which demand good spatial ability. [*For more about sex differences in spatial ability and scientific aptitude, see the article by Diane F. Halpern et al. on page 44.*]

—Siri Carpenter

>> MILESTONES

Good-bye, Alex

A rare bird passes away

Alex, the African gray parrot, died young. For three decades he redefined our understanding of animal intelligence with his humanlike ability to count, describe objects and express his desires—but he was expected to live another 20 years when an undetected arterial disease took his life. Still, the legacy Alex leaves is remarkable. According to all but the most stubborn critics, he demonstrated skills far beyond mere mimicry, suggesting that he was, in fact, a thinking being who truly understood the meaning of his words. He could apply newly learned concepts to novel situations and often used his limited vocabulary in inventive ways. For instance, when presented with an apple for the first time, he reportedly called it a "banerry," a portmanteau of the familiar labels "banana" and "cherry."

To teach Alex to talk, psychologist Irene Pepperberg of Brandeis University refined the "model-rival" technique, in which a third party demonstrates the correct response and competes for the teacher's attention. Sometimes this third party was another scientist in Pepperberg's lab; sometimes it was Alex, helping to train a younger bird. This role reversal is such a powerful learning tool that clinicians are now successfully using the technique with autistic children—extending Alex's scientific contribution far beyond the study of bird brains. —*Karen Schrock*

>> PERCEPTION

Perfect yet Imperfect

An exceptional musical skill yields clues to auditory processing

If someone plunks a random piano key, a tiny minority of people can identify the note based on its sound alone. These people boast perfect pitch, the ability to recognize individual sound frequencies without any external reference. But even these gifted few are not truly perfect. A new study shows that their errors, though subtle, provide a previously unseen glimpse into how biological and environmental factors together shape hearing.

Absolute pitch, commonly known as perfect pitch, results from the confluence of early musical training and a rare genetic endowment. Yet the neurology underlying absolute pitch (and its converse, congenital tune-deafness, or amusia) remains obscure. In the new study, researchers identified about 1,000 people who could instantly and effortlessly label each of a series of randomly presented acoustical tones. Results revealed that people with absolute pitch formed a distinct clump of scores, far outside the normal range of ability. "There are people who have this exquisitely perfect pitch-naming ability, and the rest of us are just guessing," says the study's lead author, geneticist Jane Gitschier of the University of California, San Francisco. That fact, combined with previous family heritability studies, suggests that, unlike most complex traits, perfect pitch may be governed by only one gene or at most very few.

The study also exposed an Achilles' heel for people with absolute pitch: the notes surrounding A. Volunteers with perfect pitch were far more likely to mistake a G-sharp for an A than to make any other error. They also perceived A-sharp frequently as A. The researchers suggest that this pattern may reflect the use of the note A as a universal tuning frequency in bands and orchestras. As a result of this disproportionate exposure, the group hypothesizes, the note may act as a "perceptual magnet," fooling the mind into lumping nearby tones into the A category.

In its ongoing research, Gitschier's group is trying to isolate a gene that governs absolute pitch, with the goal of then probing its molecular machinery. Ultimately, Gitschier says, she hopes to use absolute pitch as a platform for better understanding how the brain changes as a result of experience—a phenomenon known as neuroplasticity. The new findings, according to Dennis Drayna, a geneticist at the National Institute on Deafness and Other Communication Disorders who studies pitch perception, "open the door to a powerful and precise measure of learning and neuroplasticity within the auditory system. You can look at this only in people who have absolute pitch because those are the only people for whom this learning effect is going to be stable and measurable." —*Siri Carpenter*

RICK FRIEDMAN *Corbis (left)*; AGE FOTOSTOCK *(right)*

How Do Neurons Communicate?

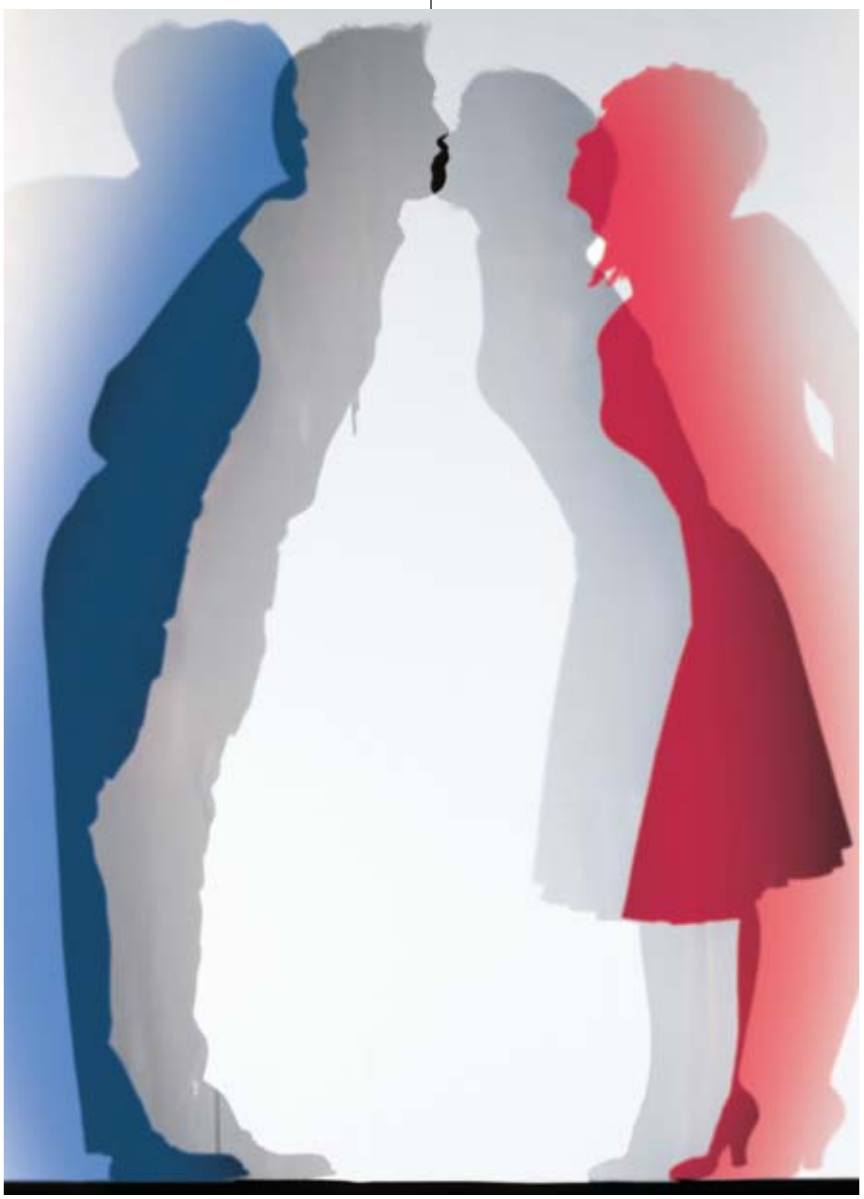
The answer is surprisingly elusive—and the subject of intense debate

BY KAREN A. FRENKEL

WE SAY something is "rocket science" when it is stunningly complex. But perhaps "neuroscience" would be a more apt metaphor—the more we learn about the brain, the more new questions arise. Case in point is a seemingly simple question: How do brain cells communicate? We know they use chemicals to send messages to one another. But exactly how do neurons release these neurotransmitters and then ready themselves to send out another rapid-fire message?

This operation takes place on a vanishingly small scale—scientists cannot actually watch the process, so they have to rely on less direct measures to determine what is going on. And because such data can often be interpreted in multiple ways, a controversy about neurotransmitter release has persisted for decades. Recent advances in laboratory techniques have escalated the debate, and the promise of finally understanding this basic cellular mechanism has set the stakes high. The answer is vital because the chemicals in our brain are implicated in everything from thought and emotion to mental illness, addiction and disease.

We already know much about the journey of a neurotransmitter. Take, for example, dopamine: Within each neuron, the chemical is contained in vesicles, small balloonlike sacs that transport material throughout the cell. When a vesicle gets an electrical signal, it carries the dopamine to the cell wall and releases it into the synapse, the space between neurons. In dopamine's case, the signal could be an electrical impulse generated by your taste buds after they receive a morsel of chocolate cake. The signal causes the vesicle to release its dopamine load, which floats in the synapse until it is detected by other neurons that receive the message, "This is pleasurable!"



Do neurons release their chemical messengers with a brief kiss?

SIRI STAFFORD *Getty Images*

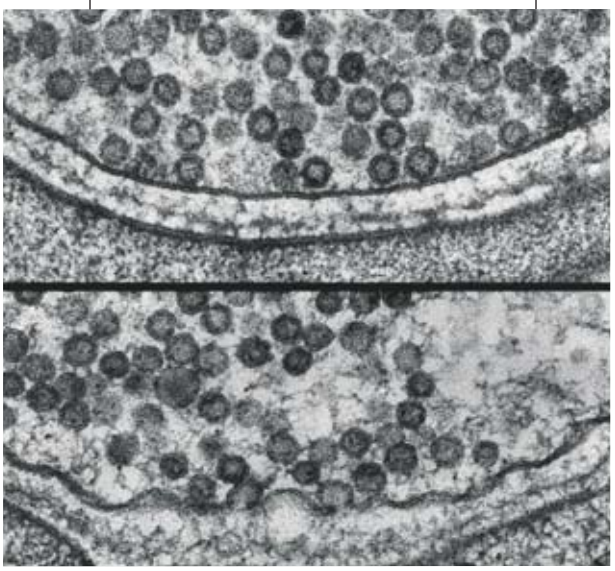
But what happens to a vesicle after it dumps its dopamine? This is where the debate comes in. With a finite number of vesicles, how do cells rapidly respond to subsequent impulses? Scientists have proposed two main opposing mechanisms for vesicle recycling, much like the two primary options available for recycling glass bottles. The fast way is to leave the bottles intact and simply refill them. The slower method involves completely melting down the bottles and making new ones. In cells, the big question is, Are vesicles ever recycled the fast way? That is, can they briefly touch the cell wall, release their contents and then disengage while retaining

> "Opponents have **moved the goalposts** from whether 'kiss and run' exists or not to how prevalent it is," one expert says.

their shape? Or are vesicles always completely absorbed into the cell wall and then reformed later?

Kiss and Run

When scientists first began isolating vesicles and studying them, it was thought that these storage containers always completely fused with the cell wall, were broken down, and then reassembled later at a kind of cellular bottle factory. In 1961 researchers found that vesicles were coated with a protein. In 1973 biophysicists John E. Heuser, now at Washington University School of Medicine, and Thomas S. Reese of the National Institutes of Health found this protein to be an essential player in vesicle reconstitution. Two years later the protein was purified and named clathrin. Clathrin-aided assembly is now considered the classical model of vesicle fusion, but it turns out to be rather slow. Researchers can measure how long vesicle recycling takes by monitoring the cell wall's ability to store electrical charge, or its capacitance. When a vesicle collapses into the cell wall, the cell's capacitance increases, and when the vesicle is reconstituted and breaks away again the capacitance returns to normal—and the entire process takes about 30 seconds.



In cells, neurotransmitters are contained within vesicles, which appear as small black circles in this electron micrograph. The bottom panel shows vesicles fully collapsing into the cell wall as they release their contents into the surrounding space.

JOHN E. HEUSER *Washington University in St. Louis*

Half a minute seems an eternity in the context of the nervous system, which must react and respond to dozens of stimuli every second. In 1973 biologist Bruno Ceccarelli first proposed a quick recycling method, dubbed "kiss and run," to account for fast transmitter release and rapid firing of synapses in frogs. Kiss and run also seemed to explain static images captured by electron microscopy that showed a vesicle at a cell wall with only a narrow passage opening into the synapse—it did not appear that the vesicle was in the process of completely collapsing. Over the years, more sophisticated experiments have suggested that kiss and run accounts for at least some, if not all, vesicle recycling events. Many neuroscientists, including Richard W. Tsien of Stanford University, use fluorescent dye to track the movement of vesicles in single neurons. If a vesicle fully collapsed after unloading its contents, the dye would be expected to dissipate into the synapse. Tsien showed that only some fluorescent markers dispersed, suggesting that the vesicle remained intact after releasing its cargo—consistent with the kiss-and-run scenario.

But others have found exceptions using this and similar dye techniques, and they doubt kiss and run's existence. Timothy A. Ryan of Weill Cornell Medical College thinks the evidence is ambiguous at best: "The data can be interpreted in other ways that don't necessarily imply kiss and run." He cautions against inventing a mechanism to explain observations of a very rapid neuronal response.

Most researchers, however, are starting to accept that both mechanisms probably exist. "It may be that vesicles undergo kiss and run on their way to an eventual full-collapse event," Tsien says. Ling-Gang Wu of the NIH recently measured electrical activity in a brain center for auditory processing in rats and found that kiss and run happened in 3 to 17 percent of recycling events. Kiss-and-run doubter Ryan points out that Wu is the first kiss-and-run proponent who admits that it occurs in a minority of events—an interpretation, Tsien says, that indicates the debate is no longer about kiss and run's existence. "Opponents have moved the goalposts from whether it exists or not to how prevalent it is. We happily accept their implicit concession and are willing to debate how important it is," Tsien says.

Although most experts do not feel that this debate will be over soon, they agree on one thing—in the process of trying to sort out the details of vesicle recycling, we are sure to learn a great deal about the way neurons work. Pinpointing exactly how neurotransmitters are created and how vesicles transport and release them could lead the way to new treatments for depression, Parkinson's disease, autism and epilepsy, to name just a few neurotransmission-related disorders. And that kind of knowledge is the real goal. M

(Further Reading)

- **Curbside Recycling at the Synapse.** Kendall Powell in *Journal of Cell Biology*, Vol. 170, No. 2, page 166; 2005.

Touching Illusions

Startling deceptions demonstrate how tactile information is processed in the brain

BY VILAYANUR S. RAMACHANDRAN AND DIANE ROGERS-RAMACHANDRAN

HUMANS, LIKE ALL PRIMATES, are highly visual creatures. Most of the back of our brain is devoted to visual processing, and half of the cortex is involved with sight. In addition, when visual inputs conflict with clues from other senses, vision tends to dominate. This supremacy is why, for example, ventriloquists are so compelling. We see the dummy talking, and we are fooled into hearing the voice coming from it—a case of what scientists call "visual capture." (With eyes closed, however, we can correctly localize the dummy voice to the ventriloquist.)

If information from vision and touch are incompatible, visual dominance may cause us to actually feel things differently than if we relied only on touch (without looking).

Curved Touch

In a simple but striking demonstration by James Gibson in the 1930s, a subject is first presented with a short straight metal rod and asked to feel it with his eyes closed. Of course, he correctly feels it is straight. He then lets go of the rod and is asked to open his eyes and look down at it. Unbeknownst to him, it is the same rod but viewed through a wedge prism, which causes the rod to appear curved rather than straight. Not surprisingly, he now reports seeing a curved rod. But what happens when he reaches out and touches the rod while looking at it? Subjects reported nothing unusual: they noticed no rivalry, instability or averaging between the senses; the rod that they saw as curved they simply also felt as curved.

In short, vision redirects the tactile perception so that no conflict is experienced. Similarly, the late Irvin Rock of the University of California, Berkeley, showed that when shape or size perception for single simple objects was made to conflict between the senses (by the introduction of distorting lenses), perception conveyed by active touch was modified to conform to visual perception.

a

Yet another example of vision influencing touch occurs in patients with phantom limbs. After amputation of an arm, the vast majority of patients continue to feel vividly the presence of the missing arm, a phenomenon termed phantom limb in the late 1800s by physician and author Silas Weir Mitchell. Many people report that their phantom limb is frozen, paralyzed in a constant or fixed position, and that this is sometimes painful.

We wondered whether touch sensations in the phantom arm could be influenced by visual input. We positioned a mirror on the table in front of

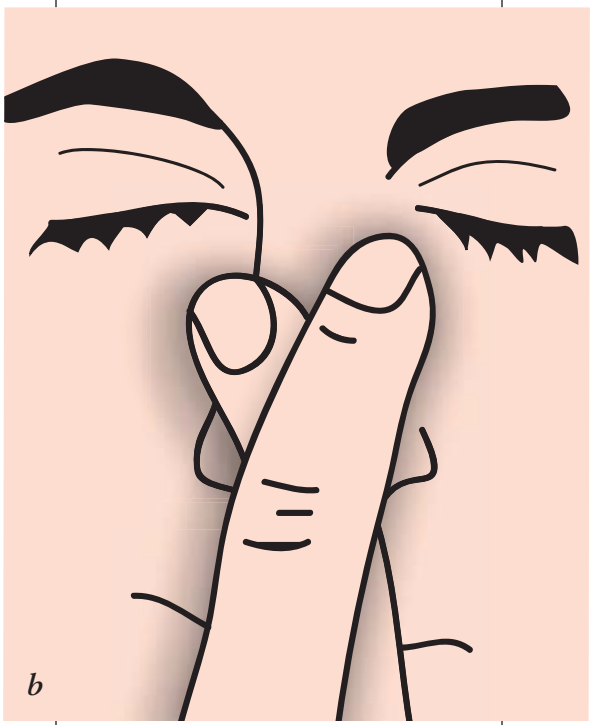
When he looked at the reflection of his normal hand in the mirror, he felt the phantom being **visually resurrected**.

JASON LEE

So the brain interprets the tactile experience as "I must have **two noses.**"

a patient, along his midline, and asked him to position his intact arm and stump/phantom hand symmetrically on either side of the mirror (*a*). When he looked at the reflection of his normal hand in the mirror, he experienced the phantom being visually resurrected. Remarkably, if the patient moved his normal hand while looking at its reflection in the mirror, the previously frozen phantom seemed to become animated; he not only saw the hand but also *felt* it move. In some cases, this sensation seemed to alleviate the pain associated with the phantom.

The visual-capture effect also indicates our need for a single, sensible narrative of the world. That is, we (our brains) tend to reinterpret or discard some information, even when doing so may produce errors or illusions (as with the ventriloquist). This influence of vision has resulted in a kind of vision chauvinism in research, leading scientists to pay less attention to the other senses.



Touched in the Head?

The neural basis of these intermodality illusions has not been studied in detail. Recent work by Krish Sathian of Emory University and Alvaro Pasqual-Leone of Harvard University suggests that somatosensory signals (those having to do with touch) may be seen in the primary visual cortex under certain circumstances—for example, in blind Braille readers. The tactile signals processed in the somatosensory centers of the brain may actually send feedback all the way to the very early stages of visual processing, instead of being merely combined at some higher level. Studies on visual capture suggest that the converse may also be true—namely, that visual input may project to what is traditionally considered primary somatosensory cortex. These interactions between the senses, in addition to informing us about brain mechanisms for information processing, may also provide a useful tool for rehabilitation for neurological disorders.

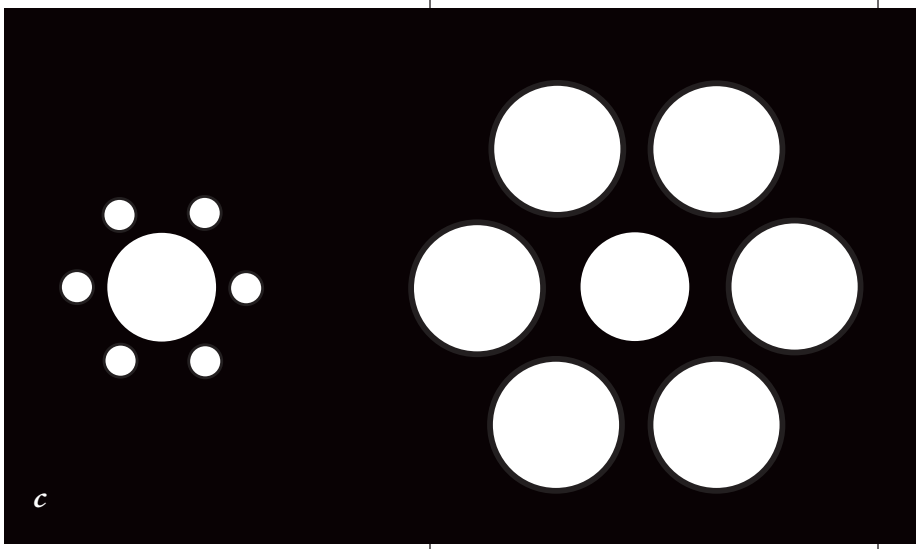
We would like to consider here some tactile illusions that bear a striking similarity to visual illusions. Try the following experiment. Place two coins in your freezer till they are chilled (maybe 20 minutes). Remove them and place them on a table flanking a similar coin that has been kept at room temperature, so that the three coins now form a row. Now place the tips of the index and ring finger of one hand on the two cold coins and the middle finger on the middle coin. Amazingly, the middle finger feels equally cold. Perhaps the temperature-sensing pathways of the brain simply do not have the resolving power to discern two discrete sources. Yet the middle finger does not feel cold unless it is in contact with a neutral coin; if there are no tactile sensations emerging from it, the brain is reluctant to "fill in," or ascribe cold to, this region.

But how "clever" is this filling-in mechanism? What if the middle finger pressed against velvet or sandpaper rather than a coin? Does it have to be similar to what is being touched by the index and ring fingers? If so, how similar? And does this interpolation of cold occur early in sensory processing—for example, in the spinal cord or thalamus (the "gateway" for sensory inputs to the brain)? Or does it happen "higher up" in later processing stages in the brain?

One way to find out is to see what happens if you simply bend the middle finger upward and then put the middle finger *of the other hand* in its place. The illusion now disappears, suggesting that the filling in occurs at an early stage of tactile information processing, not at the higher level of space representation in the brain. (We know this occurs at an early stage because the sensory signals from two hands project to two separate hemispheres in the brain; information from them can be compared only at a relatively late stage of processing.)

What if the two outer coins were very hot and icy cold, respectively; would the middle coin take on the average temperature, or would it alternate between the two? What about an intermediate case? Say you crossed the index finger under the middle digit, so that you formed a row with the index between the ring and middle fingers, the middle and ring fingers resting on the cold coins. Would the index finger now feel cold because of its intermediate location in space?

The middle disk at left is the **same size** as the one at right, but the left looks larger because it is surrounded by small disks.



The reader might wish to dream up his or her own experiments: that is what makes the study of perception so much fun. You do not need to be an expert to do experiments that have far-reaching implications. If you attempt such an experiment, we would love to hear from you.

Let us try something different. Cross your left middle finger over your left index finger, making a small V at the end. Now place the V formed by the fingers on your nose (*b, preceding page*). Astonishingly, many people who perform this "Aristotle Illusion" maneuver report a distinct feeling of having two noses! How is this effect possible?

One way to interpret the phenomenon is to realize that given the normal, habitual spatial arrangement of the fingers, the only way the *left* side of your left middle finger will be stimulated simultaneously with the *right* side of your left index finger is when they are touching two objects. So the brain interprets the tactile experience as "I must have two noses." According to psychologist Stuart Anstis of the University of California, San Diego, the nose is not the only appendage in which perceptual doubling can be produced.

Last, look at the visual illusion on this page (*c*). Believe it or not, the middle disk in the left panel of circles is the same size as the one on the right, but the left looks larger because it is surrounded by small disks. This optical trick is a powerful demonstration of the contextual nature of perception. (The skeptical reader may make a cardboard occluder with two holes to directly compare the two.) Is there an equivalent of this effect for touch?

Jelly or Velvet

The following demonstration may be a related effect. Get some coarse chicken-cage mesh, preferably mounted in a wooden frame. Then hold the mesh between the palms of your hands. Nothing peculiar so far. Now start rubbing your palms against each other with the wire between them. Remarkably, your palms will feel like jelly or velvet. The cause of this striking illusion has yet to be determined. One possibility is that it has something to do with sensing and signaling the contrast between the sharp wire and the "neutral" touch sensations on the skin—the opposite of sharp being velvety or jellylike. A version of this illusion can be found in many science museums.

You can even get your hands to "float"—a well-known trick, sometimes called the Kohnstamm effect, reintroduced to us by our 11-year-old son, Jayakrishnan Ramachandran. Stand in the middle of an open doorway and use your arms to apply outward pressure on the two sides as if you were pushing them away from your body. After about 40 seconds, suddenly let go and relax, stand normally and just let your arms hang by your sides. If you are like most of us, your arms will involuntarily rise up as if pulled by two invisible helium balloons. The reason? When you apply continuous outward force, your brain gets used to this as the "neutral state"—so that when the pressure suddenly disappears, your arms drift outward.

This simple demonstration shows that the sensory areas of your brain are not the passive recipients of signals from your sense organs. Instead we should think of them as being in a state of dynamic equilibrium with the outside world, an equilibrium point that is constantly shifting in response to a changing environment. **M**

VILAYANUR S. RAMACHANDRAN and DIANE ROGERS-RAMACHANDRAN are at the Center for Brain and Cognition at the University of California, San Diego. They serve on *Scientific American Mind*'s board of advisers.

Because of other commitments, the Ramachandrans are taking an issue off. This is a previously published column.

(Further Reading)

◆ **The Sensory Hand: Neural Mechanisms of Somatic Sensation.** Vernon Mountcastle. Harvard University Press, 2005.

(calendar)

December

3–4 Snapshots of our brain in action reveal its form and function, from molecules and cells to the grand orchestration of complex systems. The multidisciplinary symposium **What Do We Want to See in Brain Imaging?** will highlight recent technological achievements as attendees explore the potential for neuroimaging to revolutionize our understanding of the mind.
London
http://edab.dana.org/brain-imaging_en.cfm

5 On this day in 1955 the U.S. Food and Drug Administration approved the stimulant methylphenidate—sold as **Ritalin**—for the treatment of ailments such as depression, chronic fatigue and narcolepsy. During the 1960s the drug was found to help people with "hyperkinetic syndrome," known today as attention-deficit hyperactivity disorder (ADHD) and now widely diagnosed in children. Recent experiments indicate that Ritalin may work by boosting levels of dopamine in the brain, helping to focus attention.

7 Imagine a world much like our own, except that every person's true character is embodied in his or her own inseparable animal companion—be it a panther, owl or snake—which serves as a moral guide. In the new movie ***The Golden Compass***, based on the first book of Philip Pullman's award-winning *His Dark Materials* trilogy, this world is in danger of being destroyed. Twelve-year-old Lyra embarks on a dangerous quest to find out what great evil is stirring, relying only on her youthful intuition and a mysterious truth-telling compass as a guide.
New Line Studio
www.goldencompassmovie.com

12 The way we use words reveals much about the way the brain works, according to Harvard University psychologist **Steven Pinker**. Join the best-selling author as he discusses his new book, *The Stuff of Thought: Language as a Window into Human Nature,* at the Stevens Institute of Technology's Center for Science Writings.
Hoboken, N.J.
www.stevens.edu/csw

19 In the film adaptation of the autobiographical book ***The Diving Bell and the Butterfly***, French journalist Jean-Dominique Bauby suffers a stroke that paralyzes most of his body. With a functional left eyelid serving as his only means of communication, Bauby dictates in 200,000 blinks a memoir chronicling life locked in an unresponsive body.
Miramax Studio
www.miramax.com/uf_index.html

22 Why do we dream? The answer remains elusive. *Discovery Health* investigates the science behind the universal phenomenon in the new documentary ***Dreamzone***. Meanwhile read our experts' take on dreaming in this issue's "Ask the Brains," on page 84.
9 P.M. (ET/PT)
http://health.discovery.com

24 Benjamin Rush, the **"Father of American Psychiatry,"** was born on this day in 1745. The influential physician and professor signed the Declaration of Independence and penned the first American textbook on mental illness, *Medical Inquiries and Observations, Upon the Diseases of the Mind.* Because of this seminal work, the emblem of the American Psychiatric Association now bears Rush's portrait.

January

4 Happy 60th Birthday to what is arguably the **most scandalous scientific publication ever**: the first installment of the *Kinsey Reports.* The unprecedented work described Indiana University zoologist Alfred Kinsey's research into human male sexual behavior, and it opened the door to the scientific study of sexuality. The best-selling book and Kinsey's subsequent report on women were greeted with shock and outrage at a time when topics such as sexual orientation, extramarital sex and sadomasochism were rarely openly discussed—and never closely analyzed.

27–31 When scientists are designing robots that can move or "see," they often look to nature for inspiration. But at the eighth annual **Human Vision and Electronic Imaging Conference**, neuroscientists and engineers will not only apply their knowledge of our visual system to robots, they will also discuss how the pursuit of human-like technology can inspire a better understanding of vision, perception and cognition in people.
San Jose, Calif.
http://electronicimaging.org/call/08/conferences

BETTMANN/CORBIS

Compiled by Karen Schrock and Peter Sergo. Send items to editors@SciAmMind.com

BORED?

Don't blame your job, the traffic or your mindless chores. Battling boredom, researchers say, means finding focus, living in the moment and having something to live for By Anna Gosline

In a quiet, darkened lecture room, you begin a frustrating fight against fatigue. The overhead projector hums, and you cannot concentrate on the slides. You stop absorbing information and doodle mindlessly. The professor lost you eons ago. You are bored.

Virtually everyone gets bored once in a while. Most of us chalk it up to a dull environment. "The most common way to define boredom in Western culture is 'having nothing to do,' " says psychologist Stephen Vodanovich of the University of West Florida. And indeed, early research into the effects of boredom focused on people forced to perform monotonous tasks, such as working a factory assembly line.

But boredom is not merely an inherent property of the circumstances, researchers say. Rather this perception is subjective and rooted in aspects of consciousness. Levels of boredom vary among people: some individuals are far less prone to ennui than others—and some, such as extroverts, are more susceptible to this feeling.

Thus, a new generation of scientists is grappling with the psychological underpinnings of this most tedious of human emotions—and they have found that it is more complicated than is commonly known. Researchers say that boredom is not a unified concept but rather comes in several flavors. Level of attention, an aspect of conscious awareness, plays an important role in boredom, such that improving a person's ability to focus may therefore decrease ennui. Emotional factors can also contribute to boredom. People who are inept at understanding their feelings and those who become sucked in and distracted by their moods are more easily bored, for example.

Staving off tedium is no mundane matter. People who are predisposed to boredom are more likely to suffer from ills such as depression and drug addiction; they also tend to be socially awkward and poor performers at school or work. Getting at the origins of boredom may lead to ways to prevent and treat such pathologies and detrimental behaviors.

Monotony in the Mind

Researchers have tackled the topic of boredom for nearly a century. In the early days they deliberated on the effects of inherently tedious tasks, inspired by the hoards of bored and badly performing workers in factories. For instance, in a 1926 paper published in the *British Medical Journal,* psychologist A. Hudson Davies of the National Institute of Industrial Psychology in the U.K. reported that boredom is akin to mental fatigue and is caused by repetition and lack of interest in the minute and fragmented tasks of the production assembly line. Davies also noted individual differences in boredom susceptibility among factory workers: "There are still people who are not bored by work of this kind and peo-

PHOTOILLUSTRATION BY AARON GOODMAN

People who are often bored are **at greater risk** for anxiety, depression, and drug or alcohol addiction.

ple who, even on the most varied work, maintain a steadily depressed attitude to life and complain bitterly of monotony."

In the late 1930s psychologist Joseph Barmack of the City College of New York was among the first to study boredom's basis in a laboratory setting. He proposed that boredom is a sleeplike feeling, and he found that stimulants—a trio of amphetamines, ephedrine and caffeine—reduced reports of fatigue, sleepiness, inattention and boredom during repetitive tasks, such as adding up a series of large numbers. Giving money to his student subjects also seemed to pique their interest, suggesting the tiresome feelings were a combination of low arousal and insufficient motivation.

More than a decade later, in a 1951 book entitled *Organization and Pathology of Thought,* Austrian-born psychoanalyst Otto Fenichel identified a type of boredom that results from the repression of a person's drives and desires and leads to apparent aimlessness. Fenichel contrasted such "pathological" boredom with normal boredom, which, he wrote, arises simply "when we must not do what we want to do, or must do what we do not want to do."

Research on boredom continued in a sparse and piecemeal fashion for the next 30 years. Then, in 1986, psychologist Norman D. Sundberg, now emeritus professor at the University of Oregon, and his then student Richard F. Farmer, now at the Oregon Research Institute, developed perhaps the most unifying piece of research on boredom, resulting in the 28-question Boredom Proneness Scale (BPS), the first full psychometric scale designed to measure boredom as a trait [*see box on page 25*].

The BPS tests people for their propensity to be bored across different situations. That is, almost everyone experiences the transient type of world-weariness that arises from situations that are undeniably repetitious, monotonous or constraining—such as waiting in line. But some people experience boredom much more frequently. They might need more excitement from life, experience leisure-time boredom (arising from an inability to amuse themselves), or suffer from a kind of "existential" ennui that stems from an overarching lack of meaning or purpose in life.

People who are often bored are at greater risk of developing anxiety, depression, and drug or alcohol addiction; displaying anger, aggressive behavior and lack of interpersonal skills; and performing poorly at work and at school, among other problems, according to work that Vodanovich and his colleagues have conducted over the past two decades.

Need for Novelty

From one vantage point, boredom susceptibility boils down to two major factors, suggests a 2005 analysis of the BPS by Vodanovich and psychologists J. Craig Wallace of Oklahoma State University and West Florida's Steven Kass. The first is external stimulation, or the need for novelty, excitement and variety. Men, who are generally more bored than women, score higher here, according to Vodanovich. "Men are more likely to say, 'There is not enough stuff coming through the environment, and that's why I am bored,'" he explains.

This need for external stimulation may explain why extroverts tend to be particularly prone to boredom. Many early studies on the performance of monotonous tasks found that extroverts often falter and lose accuracy much earlier than their introverted counterparts. The reason, according to personality pioneer Hans Eysenck of the Institute of Psychiatry in London, is

FAST FACTS
Dissecting Dullness

1» **Most people blame boredom on the circumstances, but psychologists say this emotion is highly subjective and rooted in aspects of consciousness—and that levels of boredom vary among people. Some individuals are less—and others considerably more—likely to be bored than others.**

2» **Boredom is not a unified concept but may comprise several varieties, including the transient type that occurs while waiting in line and so-called existential boredom that accompanies a profound dissatisfaction with life.**

3» **Boredom is linked to both emotional factors and personality traits. Problems with attention also play a role, and thus techniques that improve a person's ability to focus may diminish boredom.**

that extroverts require a constant and changing supply of stimulation to achieve their optimal arousal levels.

Consistent with this idea, extroverts tend to score higher on the classic sensation-seeking scale developed in the 1960s by University of Delaware psychologist Marvin Zuckerman. This scale, meant to measure an individual's hunger for stimuli, includes questions designed to rate boredom susceptibility.

Not all studies have found a connection between extroversion and boredom, however, and some extroverts might successfully avert boredom by finding ways to inject a little intrigue into otherwise dull tasks. In 1975 psychologist A. B. Hill of the University of Keele in England reported that among 32 college students who were asked to perform a mind-numbing task involving picking up and placing pushpins, the 16 extroverts showed much greater variation in the way they performed the task than did the 16 introverts—in effect, increasing their level of stimulation by changing the work in subtle but interesting ways.

In other words, although extroverts may generally seek out more external stimulation, they may vary in the ability to generate their own stimulation—the second major factor Vodanovich teased out of the BPS. Creative people with many hobbies and interests, those who have the ability to keep themselves occupied in all manner of circumstances, tend not to become bored easily. Says Sundberg: "I believe that one should be able to sit like a Buddhist monk in complete silence and yet not be bored—and to find within the inner mind, the life, the entertainment and the growth."

In the absence of these inner amusement skills, the external world will always fail to provide enough excitement and novelty. "The brain is always seeking stimulation and over time it takes more and more. It's a losing battle. You just cannot get enough," Vodanovich says.

A longing for thrills to drive away ennui may lead people to indulge in destructive, sensation-seeking activities, including smoking, vandalism, gambling and drugs. A 2005 study of 92 Scottish teenagers, for example, found that boredom was among the top reasons stated for taking drugs. "Drug use takes place during downtime when the person would have otherwise been entertaining [himself or herself]," says clinical psychologist McWelling Todman of the New School for Social Research, who studies boredom in psychiatric and drug-recovery communities.

BETTMANN/CORBIS

Early research on boredom focused on the psychological effects of inherently tedious tasks, such as those performed on a factory assembly line.

Paying Attention

Boredom is also linked to problems with attention. After all, it is hard to be interested in something when you cannot concentrate on it. Scientists have even demonstrated this by manipulating a test environment so that people have trouble engaging in certain tasks.

In one classic 1989 experiment, psychologists James Laird and Robin Damrad-Frye of Clark University discovered that very low level distraction such as a quiet television turned on in the next room led participants to describe a listening comprehension task as "boring." Unaware of what was distracting them, the subjects could find no other explanation for their inattention. But when the TV was blaring, the subjects instead commented that the sound made it impossible to focus. Without any distraction, some students actually said that what they had heard in the comprehension exercise was stimulating. The results thus support the authors' hypothesis that "the essential behavioral component of boredom is the struggle to maintain attention."

Boredom may also grow out of a pathological inability to focus. A 2003 study by Vodanovich, Wallace and Kass found that among 148 college students, scores on the BPS were correlated with

Some research indicates that distraction, such as a television on in the background, could make an otherwise interesting book seem dull.

People who are prone to **lapses in attention** are more easily bored, one study suggests.

measures for adult attention-deficit hyperactivity disorder (ADHD), hinting that a tendency to be bored may be the result of an attention deficit.

Cognitive neuroscientist Daniel Smilek of the University of Waterloo in Ontario, along with Waterloo psychologists Al Cheyne and Jonathan Carriere, has linked boredom proneness to everyday lapses in attention—the type that cause a person to, say, put the milk in the cupboard and the cereal in the fridge. In June 2007 the Waterloo team reported testing 304 college students for their tendency toward daily attention lapses and their awareness of feelings and surroundings. The students were also assessed for everyday forgetfulness, distractibility and clinical depression.

The researchers found that the students who were prone to memory lapses and attention failures scored relatively high on the BPS. What is more, statistical models suggested that attention failures underlay the elevated scores for boredom proneness as well as for depression—an illness that shares documented similarities with boredom, including a negative mood and loss of meaning in life, Cheyne says. A chronic inability to focus on activities may render them effectively meaningless, the researchers surmise. "Attention is the common link between lack of meaning, depression and boredom," Cheyne says.

Others, meanwhile, have characterized boredom as the antithesis of something called flow, a state characterized by effortless attention, focus and absorption in a task, akin to being "in the zone" [see "Why It's So Hard to Be Happy," by Michael Wiederman; SCIENTIFIC AMERICAN MIND, February/March 2007]. Flow, says the theory's developer, psychologist Mihaly Csikszentmihalyi of Claremont Graduate University, occurs when a person's skills match the level of challenge presented by the environment and when a task includes clear goals and immediate feedback. Tasks that are too easy, he says, are boring. In contrast, tasks that people perceive to be too difficult lead to anxiety. For example, in a study published in 2003 Csikszentmihalyi and his colleagues found that flow most often occurred among 526 high school students when challenges were high but balanced with students' perceived skills.

Not in the Mood

Emotional factors can also have an impact on attentiveness, flow and thus boredom. Work by educational psychologist Mary B. Harris, now an emeritus professor at the University of New Mexico, links boredom with mood monitoring, a tendency to scrutinize and focus on your moods. In 2000 Harris asked 170 college students to fill out the BPS, along with a questionnaire that determined how often they experienced flow and whether they were mood monitors or mood labelers, people with the ability to identify and categorize their moods.

Harris found that mood monitors scored higher on the BPS and were less likely to experience flow. She concludes that a close watch on your own emotions provides "less opportunity for intense concentration on the situation and for a flow experience to occur. For a high mood monitor, engaging in an activity will require an

(The Author)

ANNA GOSLINE is a freelance science writer in Vancouver, Canada. She is also an editor at *Inkling,* an online science magazine. She is rarely bored.

SHANNON FAGAN *Getty Images*

Test for Tedium

Are you easily bored? Take this test to find out. After each statement, score yourself from 1 (if you strongly disagree) to 7 (if you strongly agree). A rating of 4 is neutral. Score the statements marked by an asterisk in the reverse direction: give yourself 1 point if you strongly agree and up to 7 points if you strongly disagree.

Sum the values from your reactions to all 28 statements. These come from the Boredom Proneness Scale developed by psychologists Norman D. Sundberg of the University of Oregon and Richard F. Farmer of the Oregon Research Institute. A high score on the scale suggests that you get bored easily. A low score indicates that you are not prone to boredom.

In a study population tested by clinical psychologist John D. Eastwood of York University in Toronto and his colleagues, the average score was 99 and the "normal" range—into which two thirds of the population fell—was 81 to 117. Just 2.3 percent of the people in this sample scored above 135 or below 63.

___ **1.** It is easy for me to concentrate on my activities.*
___ **2.** Frequently when I am working I find myself worrying about other things.
___ **3.** Time always seems to be passing slowly.
___ **4.** I often find myself at "loose ends," not knowing what to do.
___ **5.** I am often trapped in situations where I have to do meaningless things.
___ **6.** Having to look at someone's home movies or travel slides bores me tremendously.
___ **7.** I have projects in mind all the time, things to do.*
___ **8.** I find it easy to entertain myself.*
___ **9.** Many things I have to do are repetitive and monotonous.
___ **10.** It takes more stimulation to get me going than most people.
___ **11.** I get a kick out of most things I do.*
___ **12.** I am seldom excited about my work.
___ **13.** In any situation I can usually find something to do or see to keep me interested.*
___ **14.** Much of the time I just sit around doing nothing.
___ **15.** I am good at waiting patiently.*
___ **16.** I often find myself with nothing to do, time on my hands.
___ **17.** In situations where I have to wait, such as in a line, I get very restless.
___ **18.** I often wake up with a new idea.*
___ **19.** It would be very hard for me to find a job that is exciting enough.
___ **20.** I would like more challenging things to do in life.
___ **21.** I feel that I am working below my abilities most of the time.
___ **22.** Many people would say that I am a creative or imaginative person.*
___ **23.** I have so many interests, I don't have time to do everything.*
___ **24.** Among my friends, I am the one who keeps doing something the longest.*
___ **25.** Unless I am doing something exciting, even dangerous, I feel half-dead and dull.
___ **26.** It takes a lot of change and variety to keep me really happy.
___ **27.** It seems that the same things are on television or in the movies all the time; it's getting old.
___ **28.** When I was young, I was often in monotonous and tiresome situations.

SOURCE: "BOREDOM PRONENESS—THE DEVELOPMENT AND CORRELATES OF A NEW SCALE," BY RICHARD F. FARMER AND NORMAN D. SUNDBERG, IN *JOURNAL OF PERSONALITY ASSESSMENT*, VOL. 50, NO. 1; 1986

effortful maintenance of attention, resulting in more frequent feelings of boredom." On the other hand, boredom is *less* of a problem for mood labelers. By accurately assessing their emotions, these individuals can effectively forget about them and focus on the tasks at hand.

The results mirrored those from a 1998 study of 308 college students by Vodanovich and West Florida's Hope M. Seib, in which individuals high in positive self-awareness—awareness of their own internal states—reported lower overall boredom. In contrast, those who showed a lot of negative self-awareness—characterized by judgmental ruminations—had elevated scores on the BPS.

Understanding your own internal states may be an important factor in boredom irrespective of its influence on attention. Fenichel's 1951 psychoanalytical explanation for boredom posited that repression of wants and desires leads to an aimless, meaningless state of being because the sufferer does not know what he or she wants to do.

Experimental evidence partially supports the notion that boredom can arise from an inability to identify the activities that will lead to happiness and fulfillment. In 2007 clinical psychologist John D. Eastwood of York University in Toronto and his colleagues reported that students who scored high on scales of alexithymia—a deficiency in understanding and describing your

An inability to know what will **make you happy** can lead to a profound, existential ennui.

own feelings, accompanied by an inhibited emotional and fantasy life—also scored higher on the BPS.

Evidence that such a cause for boredom exists independently of attention problems comes from unpublished work by Eastwood's group in which the researchers analyzed scores from 206 students on the BPS, a diagnostic for adult ADHD, and a scale of emotional awareness. They found that both higher levels of inattention and reduced emotional awareness explain a significant, but separate, amount of the variation in students' proneness to boredom.

At its extreme, an inability to know what will make you happy can lead to a more profound existential boredom arising from a pervasive sense of meaninglessness. Existential boredom might also occur when a person abandons important life goals and dreams because of practical concerns or other pressures. In 2000 clinical psychologist Richard Bargdill, now at Saint Francis University, described six cases of what he calls "life boredom," in which the neglect of life goals leads to a state of emotional ambivalence and pervasive boredom. For example, one woman who had surrendered her dream of becoming a biologist now found herself in an empty nest with a husband she loathed; another man had abandoned his wish to become an astronomer to pursue religion as his occupation. "To be bored is to be disengaged from the world," Eastwood concludes.

Combating Boredom

Treatments for boredom, like the feeling itself, come in many varieties. If boredom stems from understimulating work, a solution might be to change jobs or to enrich the working environment with new levels of complexity and challenge, Csikszentmihalyi suggests. For example, a supermarket clerk might improve service by taking the time to strike up a genuine conversation with customers. A 1970 study of long-distance truck drivers by psychologist William McBain of San Jose State College found that drivers who played mental games, such as counting passing objects, reported little boredom. They were also safer drivers.

If boredom envelops leisure time, an individual might try to develop new interests, skills or hobbies, says Vodanovich, who has struggled with his own boredom. For his part, he makes an

Boredom in the Brain

No one has yet identified the neural correlates of boredom, but one clue to the biological basis of this emotion comes from patients who have sustained injuries to their frontal cortex (*red portion of brain at right*). Such patients often experience various emotional and cognitive quirks. Among them are heightened boredom and extreme increases in sensation-seeking or risk-taking behaviors, suggesting that the experience of boredom—or its opposite—may arise in part from activity in this swath of brain tissue. Patients with frontal-cortex lesions also have attention deficits, providing an additional tie between boredom and a wandering focus.

Brain-imaging studies suggest that networks for time perception exist in the frontal lobe as well—and damage to that lobe can distort time perception. What is more, some studies suggest, boredom-prone people tend to perceive time to be passing more slowly than do those less susceptible to this emotion. Thus, disruptions in a network governing time perception in the frontal lobe could also interfere with a person's ability to become engaged in a task. —*A.G.*

CHRISTIAN DARKIN *Photo Researchers, Inc.*

effort to spice up everyday routines, by varying his driving route to the office and even the way he looks at the world around him. "You can train yourself to see the richness of the environment," he says. "If you can find a way to perceptually recognize the beauty of the world—the different colors of the leaves rather than just green, the different shapes—you are probably less likely to be bored overall."

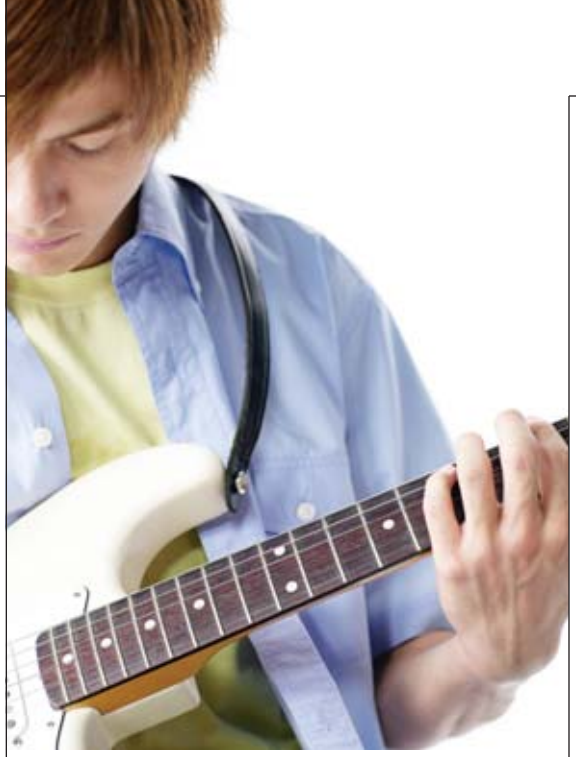
This heightened appreciation of self and immediate surroundings also lies at the heart of mindfulness, "the state of being attentive to and aware of what is taking place in the present," wrote psychologists Kirk Warren Brown of Virginia Commonwealth University and Richard M. Ryan of the University of Rochester in a 2003 paper. Mindfulness training—a practice growing in popularity in educational, medical and office settings—is rooted in Eastern philosophies of meditation. Subjects are taught to slow down, focus on their breathing and bodily feelings, and let thoughts pass freely without judgment.

Such practices may decrease boredom by making people both more attentive and less likely to obsess over their own moods. In February 2007 psychologists at the University of Melbourne reported that a 10-day mindfulness course improved the performance of novice meditators on tasks of sustained attention and working memory—and also diminished rumination and symptoms of depression—as compared with the novices who did not receive mindfulness training.

Encouraging children to entertain themselves in mentally active and imaginative ways and to avoid passive, quick-fix entertainment could also reduce boredom. "We provide children lots of entertainment in the form of television and iPods to prevent them from developing their inner skills to contend with boredom," Sundberg says. Engaging in active entertainment, such as playing sports or games, is also much more likely to produce flow, Csikszentmihalyi says.

Developing ways to cope with boredom may even help cure other ills. For example, some research hints that if former drug addicts learn to deal effectively with boredom, they are less likely to relapse. In an ongoing study of 156 addicts at a methadone clinic at Beth Israel Medical Center in New York City, Todman found that the addicts' reported level of boredom was the only reliable indicator of whether they would stay clean.

Of course, boredom also has its benefits. It can provide an opportunity for thought and reflection, many study participants observe. It can also be a sign that a task is a waste of time—and thus not worth continuing. "Rather than fighting boredom, we would do well to pause and learn from the experience," Eastwood says.



Taking up a hobby such as playing guitar can help stave off boredom.

CORBIS

Indeed, many scholars have considered boredom a catalyst for action. In his 1995 essay "In Praise of Boredom," Nobel Prize–winning poet Joseph Brodsky wrote: "When hit by boredom, go for it. Let yourself be crushed by it; submerge, hit bottom. In general, with things unpleasant, the rule is, the sooner you hit bottom, the faster you surface." Adds Vodanovich: "If you don't succumb to its negative effects, boredom is a great motivational force." M

(Further Reading)

- **Boredom: A Review.** Richard P. Smith in *Human Factors,* Vol. 23, No. 3, pages 329–340; June 1981.
- **Boredom Proneness—The Development and Correlates of a New Scale.** Richard F. Farmer and Norman D. Sundberg in *Journal of Personality Assessment,* Vol. 50, No. 1, pages 4–17; 1986.
- **The Benefits of Being Present: Mindfulness and Its Role in Psychological Well-Being.** Kirk Warren Brown and Richard M. Ryan in *Journal of Personality and Social Psychology,* Vol. 84, No. 4, pages 822–848; 2003.
- **A Confirmatory Approach to the Factor Structure of the Boredom Proneness Scale: Evidence for a Two-Factor Short Form.** Stephen J. Vodanovich, J. Craig Wallace and Steven J. Kass in *Journal of Personality Assessment,* Vol. 85, No. 3, pages 295–303; 2005.
- **A Desire for Desires: Boredom and Its Relation to Alexithymia.** John D. Eastwood, Carolina Cavaliere, Shelley A. Fahlman and Adrienne E. Eastwood in *Personality and Individual Differences,* Vol. 42, No. 6, pages 1035–1045; April 2007.
- **Everyday Attention Lapses and Memory Failures: The Affective Consequences of Mindlessness.** Jonathan S. A. Carriere, J. Allan Cheyne and Daniel Smilek in *Consciousness and Cognition.* Published online June 15, 2007.
- For more on boredom research and to participate in online surveys studying boredom and attention problems, visit **http://oops.uwaterloo.ca/bored.php**

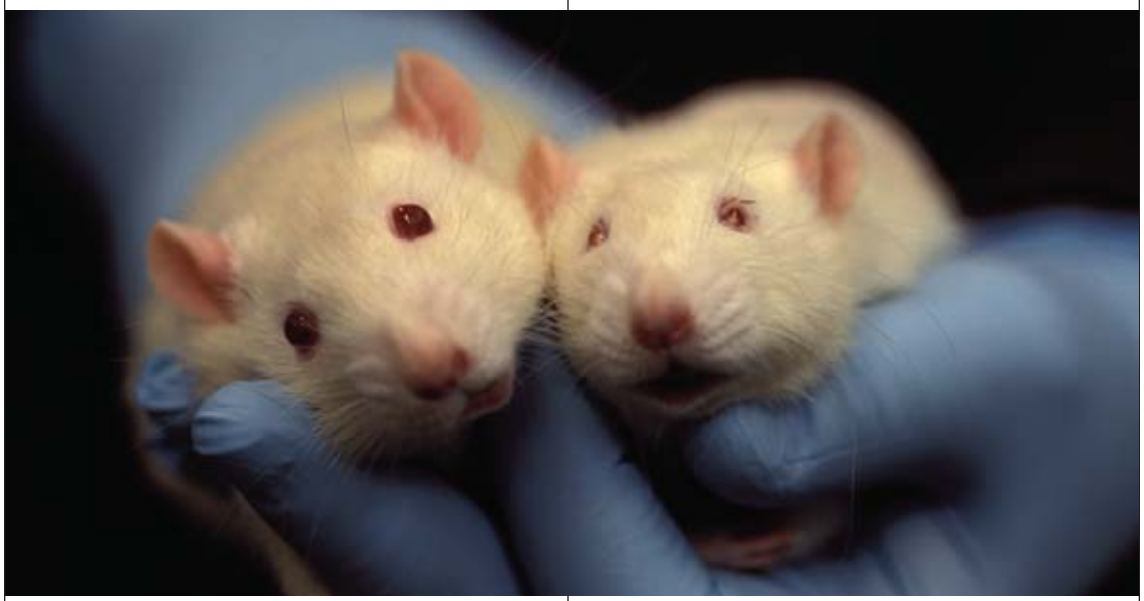
Do Animals *Feel* Empathy?

We call a callous turncoat a "rat." Rats and mice, however, are giving scientists clues to the evolutionary origins of empathy

By Frans B. M. de Waal

Bonobo mother lifts up the face of her offspring to take a closer look (*above*), and an embracing pair of young chimpanzees demonstrates affinity (*right*). Scientists are probing the evolutionary origins of empathy.

We empathize with our pets, but we have been stingy about **recognizing empathy** elsewhere among animals.



If rodents show empathy, the capacity may be widespread indeed. A mouse study has indicated greater empathy toward cage mates than toward strangers.

Apart from some rear-guard behaviorists, few people hesitate to ascribe empathy to their dogs. But then dogs are man's best friend, freely credited with lots of human sentiments. For as much as we empathize with our canines, we have been stingy about recognizing empathy elsewhere in the animal kingdom, reserving it as a human trait. This belief is changing, however, as a growing line of research demonstrates not just empathy's existence in other animals but its subtleties and exceptions as well. And they shed some interesting light on how we developed our capacity for caring for others.

FAST FACTS

Evolution of Empathy

1» The study of empathy in animals, long discouraged by a behaviorist resistance to the attribution of human emotions to animals, is on the rise.

2» Recent work found that mice that have witnessed other mice in discomfort or pain showed more sensitivity to pain themselves.

3» The mice typically showed more apparent empathy for cage mates that were familiar to them. Males (but not females) tended to show no signs of empathy for other males that were strangers to them.

4» This mouse study bolsters evidence that even rodents exhibit something akin to empathy—and strengthens the argument that empathy arises from basic neural mechanisms that human evolution has elaborated on. In the primates, the focus is often on mirror neurons as mediators of empathetic responses.

Early Studies

The recent surge in empathy studies revives a line of research started almost half a century ago. In 1959 a paper by psychologist Russell Church in the *Journal of Comparative & Physiological Psychology*, provocatively entitled "Emotional Reactions of Rats to the Pain of Others." Church first trained rats to obtain food by pressing a lever. He found that if a rat pressing the lever saw another rat in a neighboring cage receive a shock from an electrified cage floor, the first rat would interrupt its activity—a remarkable result. Why shouldn't the rat continue to get food and simply ignore the other animal's flinching? The bigger question was whether the rats that stopped pressing the lever were worried about their companions or just afraid that something bad might happen to them as well.

Church's work inspired a brief flurry of research during the 1960s that investigated the presence of concepts such as "empathy," "sympathy" and "altruism" in animals. To avoid troublesome skepticism from colleagues, the investi-

KAREN KASMAUSKI *Corbis (above)*; FRANS LANTING *Minden Pictures (page 28, left)*; CYRIL RUOSO/JH EDITORIAL *Minden Pictures (preceding pages, right)*

gators made sure to place the topics of their research in quotation marks; the prevailing behaviorist atmosphere made mention of animal emotions an anathema. Combined with the traditional emphasis on nature's nasty side, this taboo ensured that these studies went largely ignored.

In the meantime, however, human empathy became a respectable study topic. First, in the 1970s, came studies of empathy in young children; then, in the 1980s, in adults. Finally, in the 1990s, researchers began placing humans in brain scanners to monitor them while they watched others who were in pain or distress or who had a disgusted facial expression—revealing many intriguing findings about activity in the brain. This field now produces new articles every week. But animal studies have lagged.

An Old Sorrow

This sluggish pace is changing. Slowly but steadily, nearly 50 years after Church's rat study, the evolutionary origin of empathy is becoming a hot topic, reviving interest in studies of whether animals experience this complex and socially vital connection to others. Psychologist Stephanie D. Preston of the University of Michigan at Ann Arbor and I have argued that a basic neural process, first developed in our animal ancestors, underlies even the fancy kinds of empathy that only we humans are capable of. Seeing another person in a certain situation reactivates neural representations of when we ourselves have been in similar situations; this brain activity, in turn, generates a body state resembling that of the object of our attention. Thus, to see another's pain may lead us to share it.

This empathetic capacity is in place on the very first day of a person's life. You can see it in any maternity ward, where all newborns will start crying as soon as one of them gets going. Artificial noise fails to cause the same reaction: babies are particularly sensitive to the distress calls of their own species. I have seen a similar spread of distress in young rhesus monkeys. Once, when an infant monkey had been bitten, it screamed so incessantly that it was soon surrounded by other infants. I counted eight of them climbing on top of the poor victim, pushing, pulling and shoving one another as well as the first infant. The response seemed automatic, as if the other infants were as distraught as the victim was and sought to comfort themselves as much as their companion.

Each week in Mind Matters, www.sciammind.com's expert-written "blog seminar," researchers of mind and brain explain and discuss their disciplines' most notable recent findings. In this installment, Frans B. M. de Waal and Peggy Mason consider the finding that mice may feel empathy.

Mind Matters examines a new finding every week. Join the discussion at www.sciammind.com

Young bachelor stallions nuzzling.

YVA MOMATIUK/JOHN EASTCOTT *Minden Pictures*

Empathy Is a Pain, So Why Bother?

BY PEGGY MASON

As Frans B. M. de Waal notes in the main article, the principles of biological continuity should make it unsurprising that mice act in empathetic ways similar to those seen in primates, including humans. The study by Dale J. Langford and her colleagues at McGill University bolsters that view in striking ways.

For instance, it is tempting to explain empathetic behavior in animals that we believe to have only rudimentary cognition, such as mice, by arguing that the sight of a suffering fellow mouse simply evokes an automatic fear reaction. This study undermines that explanation by showing that mice showed empathetic reactions only with cage mates; the mice seem to go far beyond being frightened by injury to accounting for whom the injured party is—friend, family, foe or stranger. This response is a significant step toward humanlike social feeling—caring for acquaintances more than for strangers, just as our empathy for someone who is hurt differs depending on whether the person is a foreigner, a national compatriot, a school chum or an immediate family member.

Reflection of Pain

So how can the brain accomplish empathy in general and empathy for pain in particular? The answer most likely involves mirror neurons, discovered more than a decade ago by Giacomo Rizzolatti and his colleagues at the University of Parma in Italy. In Rizzolatti's original 1996 study, he and his colleagues found that premotor neurons in a monkey's prefrontal cortex—neurons that routinely fire as the monkey prepares a particular movement, such as reaching out to grasp something—fired in a similar pattern when the monkey merely watched a human perform the same task.

Rizzolatti's group also demonstrated that mirror neurons fire not only in response to an observed action but also in response to the action's apparent intent. For example, a monkey may have a premotor neuron that fires when the monkey grabs a peanut to eat but not when it grabs a peanut for other reasons, such as to place it in a cup. This "grab-to-eat" neuron will fire when the monkey watches a human grab a peanut to eat it but not when the human picks up the peanut for other reasons; the neuron responds to the action's intent. Finally, mirror neurons are activated by a perception of purpose rather than of specific muscle movements: cells that discharge when the monkey watches a human reach for an object will continue to respond even if much of the movement is hidden by an opaque screen.

Critical Mass of Empathy

Other findings suggest that mirror functionality may not be restricted to neurons in the prefrontal cortex; some portion of "regular" cortical neurons in numerous areas may act as mirror neurons, too. Functional imaging experiments in humans support this possibility and suggest a potential substrate for pain empathy.

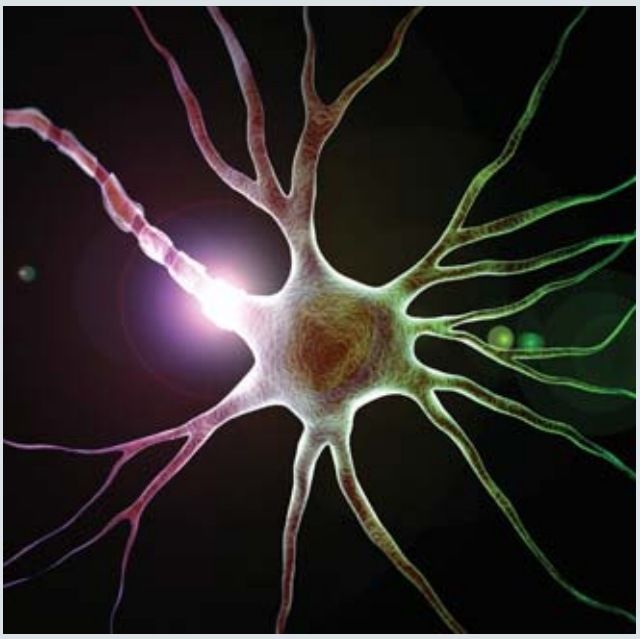
Consider, for instance, the insula and anterior cingulate. These two brain regions contain neurons that fire in relation to pain's affective component—the "I care" or "I don't like this" aspect of pain—as opposed to the discriminative—the "where, when, what type" of pain—component. When an experimenter applies a painful stimulus to a volunteer, nerve cells in the subject's insula and anterior cingulate are activated, presumably creating the negative affect associated with pain sensation. If, in fact, these affect-relevant neurons have mirror functionality, then when the volunteer watches a loved one experience pain, these neurons will discharge and create an affective state much like the volunteer would feel if she were receiving the painful stimulus herself.

A more rigorous and particularly revealing study of animal empathy came last year from psychology graduate student Dale J. Langford and her colleagues at McGill University in a paper entitled "Social Modulation of Pain as Evidence for Empathy in Mice," published in *Science* June 30, 2006. (Note that this time the word "empathy" is free of quotation marks; this absence reflects the growing consensus that emotional linkage between individuals probably has the same biological origin in humans and other animals.) This study was inspired by a puzzle that Langford and her laboratory's director, pain geneticist Jeffrey S. Mogil, found intriguing: when they tested mice from the same home cage in experiments that involved light shocks to the feet, the researchers noticed that the order in which the mice were tested seemed to affect their pain response. The first mouse would always show fewer signs of pain than the

Empathetic behavior seems a first step in developing the social obligation to care for the sick and injured.

Viewing mirror functionality as a substrate for empathetic behavior provides specific explanations for two of the findings in the Langford paper. First, pain behavior—the actions that we and other animals take when feeling pain—occurred simultaneously when two cage mates in pain could see each other. If mirror neurons underlie pain empathy, then the sight of one mouse acting in pain will elicit mirror discharge in its cage mate. When this mirror discharge is added to the activation because of the pain received directly, it may bring activity in the insula and anterior cingulate to a perceptual threshold, resulting in an emotion of "I care"—and, therefore, "I move." Mirror neurons thus provide a mechanism for synchronizing behavior within a group.

Mirror functionality also helps explain why the mice in this study showed empathetic reactions even if they suffered from a different type of pain than did the fellow sufferers they observed, as when a mouse showed more sensitivity to heat if it saw a cage mate suffering from a stomachache. Mirror functionality accounts for meaning rather than specific muscle activations; the meaning of pain is pain, even if the motor reactions to distinct pains differ substantially.



How can the brain accomplish empathy? The answer most likely involves mirror neurons, brain cells (such as that depicted in the conceptual image above) that fire in response when a subject witnesses another animal or person perform a task—or experience pain.

From Empathy to Action

Finally (as if the above discussion is not sufficiently conjectural), it is intriguing to speculate further about the role of pain empathy in socialization. Severe injuries—deep gashes, broken bones—and chronic pain isolate and incapacitate the sufferer. Humans survive such damage because other humans take care of them. Animals such as rats and mice typically do not survive, however, because other rodents do not feed them and protect them from predation. Empathetic behavior for others in pain would seem a natural first step in developing the social obligation necessary to care for sick and injured conspecifics. Although I suspect that mice are not yet ready for nursing duty, they may have taken the first step toward socialized medicine.

Peggy Mason is in the department of neurobiology at the University of Chicago, where she chairs the graduate program in neurobiology and studies the role of the brain stem in pain modulation and homeostasis.

last. Was the last mouse being sensitized to pain by seeing others in pain? Or was something else at work?

To find out, Langford, Mogil and their colleagues devised an experiment in which pairs of mice were put through a so-called writhing test. In each trial, two mice were placed in two transparent Plexiglas tubes so that they could see each other. Either one or both mice were injected with diluted acetic acid, which is known to cause a mild stomachache. Mice respond to this discomfort with characteristic stretching movements. (This is less a "writhe," really, than a sort of discomfited restlessness.) The researchers found that an injected mouse would show more of this movement if its partner displayed the same behavior than it would if its partner had not been injected. Significantly, this increased display occurred only in mouse pairs who were cage mates.

Male (and not female) mice showed an additional interesting phenomenon when witnessing a strange male mouse in pain: its own pain sensitivity would actually drop. This counterempathet-

(The Author)

FRANS B. M. DE WAAL is director of the Living Links Center at Emory University, where he studies the behavior and evolution of primates. His book describing this growing field, *Our Inner Ape* (Riverhead Books/Penguin), was chosen as a *New York Times* Notable Book of the Year in 2005.

3D4MEDICAL.COM Getty Images

The emotional connection comes first; understanding and imagination follow.

Male lions grooming each other.

ic reaction occurred only in male pairs that did not know each other, which are probably the pairs with the greatest degree of rivalry. Was the rivalry suppressing their reaction, or did they feel less empathy for a strange mouse?

(This gender effect reminds me of a wonderful study of human schadenfreude that Tania Singer, now at the University of Zurich, and her colleagues published in *Nature* in early 2006. The researchers found that in both men and women, seeing the pain of a person one has just cooperated with activates pain-related brain areas. But if a man felt he had been treated unfairly by another man in a previous exchange, his brain's pleasure centers would light up at seeing the other's pain. Such male antipathy toward rivals may be a mammalian universal.)

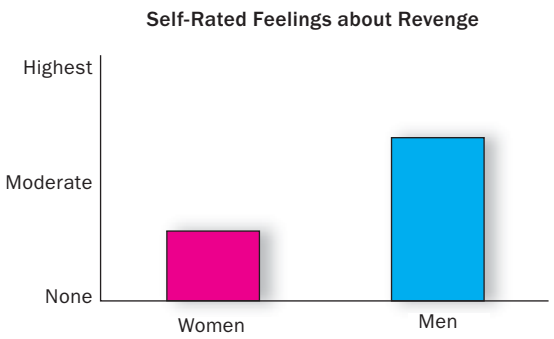
Finally, Langford and her colleagues also exposed pairs of mice to different sources of pain—the acetic acid as before and a radiant heat source that would cause pain if a mouse did not move away. Mice observing a cage mate suffering a stomachache withdrew more quickly from the heat source. In other words, the reactions of mice cannot be attributed to mere imitation, because a mouse seeing a companion in pain appears to be sensitized to *any* pain.

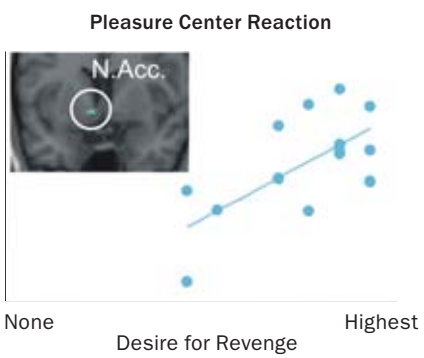
Foundation of Empathy

I admire this study greatly. It is not the kind of manipulation we would nowadays apply to primates, but it goes a long way toward confirming the tentative conclusions of the 1960s, with the benefits of more subjects and more rigorous

Turnabout Is Fair Play

Empathetic feelings can vary depending on context (*graphs*). In a study, men and women first cooperated with a partner and then saw that partner experience pain. In the men, pleasure centers in the nucleus accumbens (*blue spot in inset image at right*) activated if the partner had been unfair in the earlier exchange, indicating stronger feelings of revenge.





FRANS LANTING *Minden Pictures (top)*; SOURCE: "EMPATHIC NEURAL RESPONSES ARE MODULATED BY THE PERCEIVED FAIRNESS OF OTHERS" BY TANIA SINGER ET AL., IN *NATURE*, VOL. 439, PAGES 466-469; JANUARY 26, 2006, COURTESY OF DR. TANIA SINGER *(inset)*

We Get Comments ...

Like most blogs, Mind Matters invites reader comments and questions. Unlike most blogs, these inquiries often get answered by leading researchers—the authors of the posts that provide reviews of recent papers, as well as some of the scientists who visit the blog—and *Scientific American Mind* editors. The sampling below includes an exchange between readers and Frans B. M. de Waal. *—David Dobbs, Mind Matters editor*

It's always baffled me that any anthropomorphism of animals is considered "unscientific" until the evidence supporting a particular instance is overwhelming. Occam's razor leads one to the opposite point of view. If we accept certain types of behavior as being motivated by particular emotional or mental states in humans, it follows that, barring good evidence to the contrary, the simplest assumption would be that similar behaviors are motivated by similar internal states in animals. Any argument that can be applied to dismiss this in animals applies equally to humans. Why the false dichotomy? It makes no sense. ***—Kevin M.***

Put simply, Occam's razor relates to explanations and states that elements should not be multiplied beyond necessity. Animals being capable of empathy is by far more complex than if they weren't. There is absolutely no reason for us to assume any similarity between our behavior patterns and those of animals. To do so would be in violation of Occam's razor, not the other way around. To save ourselves confusion, it's best to wait for theories like this to be backed up by studies before contemplating what the theories might mean. ***—Nick Coad***

de Waal replies:
It's true that from a cognitive perspective, assuming empathy in animals is not particularly parsimonious. This is usually how Occam's razor is interpreted in psychology. That is a pre-Darwinian interpretation, however. I have argued elsewhere (Philosophical Topics, Vol. 27, pages 255–280; 1999) that there is a second kind of parsimony: evolutionary parsimony. This assumes that if two related species act similarly under similar circumstances, the simplest assumption is that the psychology behind their behavior is similar, too. The alternative would be to assume the separate evolution of similar behavior, which is not particularly elegant or economic. So, take your pick! I personally opt for the Darwinian version of Occam's razor.

controls. Although it does not prove that the mice feel vicarious emotions, it demonstrates that they experience a vicarious intensification of their own experience.

This demonstration justifies speaking of "empathy" outside of humanity—at least in some instances. Here we find an interesting division between psychologists, who tend to think in terms of top-down processes, and biologists, who tend to think from the bottom up. The top-down view considers the most advanced forms of empathy, such as putting yourself into another's "shoes" and imagining his or her situation, and wonders how this ability arises; the inevitable answer is advanced cognition, perhaps even language. Yet merely imagining someone else's situation is not empathy. Such imagination can be a cold affair, not unlike understanding how airplanes fly. Empathy requires emotional involvement.

Here the bottom-up view offers a better perspective. When we react to seeing someone display emotion and construct an advanced understanding of the other's situation, this process indeed involves—in humans and in some other large-brained animals—a great deal of cognition. But the emotional connection comes first; understanding and imagination follow. The mouse experiment suggests that the emotional component of this process is at least as old as our early mammalian ancestors and runs deep within us. M

(Further Reading)

- **Empathy: Its Ultimate and Proximate Bases.** Stephanie D. Preston and Frans B. M. de Waal in *Behavioral and Brain Sciences,* Vol. 25, No. 1, pages 1–20; 2002.
- **Grasping the Intentions of Others with One's Own Mirror Neuron System.** Marco Iacoboni, Istvan Molnar-Szakacs, Vittorio Gallese, Giovanni Buccino, John C. Mazziotta and Giacomo Rizzolatti in *PLoS Biology,* Vol. 3, No. 3, pages 529–535; March 2005. Published online February 22, 2005. Available at **http://tinyurl.com/2v679v**
- **Our Inner Ape.** Frans B. M. de Waal. Riverhead Books/Penguin, 2005.
- **Empathetic Neural Responses Are Modulated by the Perceived Fairness of Others.** Tania Singer, Ben Seymour, John P. O'Doherty, Klaas E. Stephan, Raymond J. Dolan and Chris D. Frith in *Nature,* Vol. 439, pages 466–469; January 26, 2006.

The Secret to Raising Smart Kids

Hint: Don't tell your kids that they are. More than three decades of research shows that a focus on effort—not on intelligence or ability—is key to success in school and in life

By Carol S. Dweck

A brilliant student, Jonathan sailed through grade school. He completed his assignments easily and routinely earned As. Jonathan puzzled over why some of his classmates struggled, and his parents told him he had a special gift. In the seventh grade, however, Jonathan suddenly lost interest in school, refusing to do homework or study for tests. As a consequence, his grades plummeted. His parents tried to boost their son's confidence by assuring him that he was very smart. But their attempts failed to motivate Jonathan (who is a composite drawn from several children). Schoolwork, their son maintained, was boring and pointless.

Our society worships talent, and many people assume that possessing superior intel-

Young people who believe that their intelligence alone will enable them to succeed in school are often discouraged when the going gets tough.

ligence or ability—along with confidence in that ability—is a recipe for success. In fact, however, more than 30 years of scientific investigation suggests that an overemphasis on intellect or talent leaves people vulnerable to failure, fearful of challenges and unwilling to remedy their shortcomings.

The result plays out in children like Jonathan, who coast through the early grades under the dangerous notion that no-effort academic achievement defines them as smart or gifted. Such children hold an implicit belief that intelligence is innate and fixed, making striving to learn seem far less important than being (or looking) smart. This belief also makes them see challenges, mistakes and even the need to exert effort as threats to their ego rather than as opportunities to improve. And it causes them to lose confidence and motivation when the work is no longer easy for them.

Praising children's innate abilities, as Jonathan's parents did, reinforces this mind-set, which can also prevent young athletes or people in the workforce and even marriages from living up to their potential. On the other hand, our studies show that teaching people to have a "growth mind-set," which encourages a focus on effort rather than on intelligence or talent, helps make them into high achievers in school and in life.

FAST FACTS

Growing Pains

1» Many people assume that superior intelligence or ability is a key to success. But more than three decades of research shows that an overemphasis on intellect or talent—and the implication that such traits are innate and fixed—leaves people vulnerable to failure, fearful of challenges and unmotivated to learn.

2» Teaching people to have a "growth mind-set," which encourages a focus on effort rather than on intelligence or talent, produces high achievers in school and in life.

3» Parents and teachers can engender a growth mind-set in children by praising them for their effort or persistence (rather than for their intelligence), by telling success stories that emphasize hard work and love of learning, and by teaching them about the brain as a learning machine.

The Opportunity of Defeat

I first began to investigate the underpinnings of human motivation—and how people persevere after setbacks—as a psychology graduate student at Yale University in the 1960s. Animal experiments by psychologists Martin Seligman, Steven Maier and Richard Solomon of the University of Pennsylvania had shown that after repeated failures, most animals conclude that a situation is hopeless and beyond their control. After such an experience, the researchers found, an animal often remains passive even when it can affect change—a state they called learned helplessness.

People can learn to be helpless, too, but not everyone reacts to setbacks this way. I wondered:

JIM CUMMINS *Getty Images (preceding pages)*; GETTY IMAGES *(above)*

The most persistent students do not ruminate about their own failure but think of mistakes as **problems to be solved.**

Why do some students give up when they encounter difficulty, whereas others who are no more skilled continue to strive and learn? One answer, I soon discovered, lay in people's beliefs about *why* they had failed.

In particular, attributing poor performance to a lack of ability depresses motivation more than does the belief that lack of effort is to blame. In 1972, when I taught a group of elementary and middle school children who displayed helpless behavior in school that a lack of effort (rather than lack of ability) led to their mistakes on math problems, the kids learned to keep trying when the problems got tough. They also solved many of the problems even in the face of difficulty. Another group of helpless children who were simply rewarded for their success on easy problems did not improve their ability to solve hard math problems. These experiments were an early indication that a focus on effort can help resolve helplessness and engender success.

Subsequent studies revealed that the most persistent students do not ruminate about their own failure much at all but instead think of mistakes as problems to be solved. At the University of Illinois in the 1970s I, along with my then graduate student Carol Diener, asked 60 fifth graders to think out loud while they solved very difficult pattern-recognition problems. Some students reacted defensively to mistakes, denigrating their skills with comments such as "I never did have a good rememory," and their problem-solving strategies deteriorated.

Others, meanwhile, focused on fixing errors and honing their skills. One advised himself: "I should slow down and try to figure this out." Two schoolchildren were particularly inspiring. One, in the wake of difficulty, pulled up his chair, rubbed his hands together, smacked his lips and said, "I love a challenge!" The other, also confronting the hard problems, looked up at the experimenter and approvingly declared, "I was *hoping* this would be informative!" Predictably, the students with this attitude outperformed their cohorts in these studies.

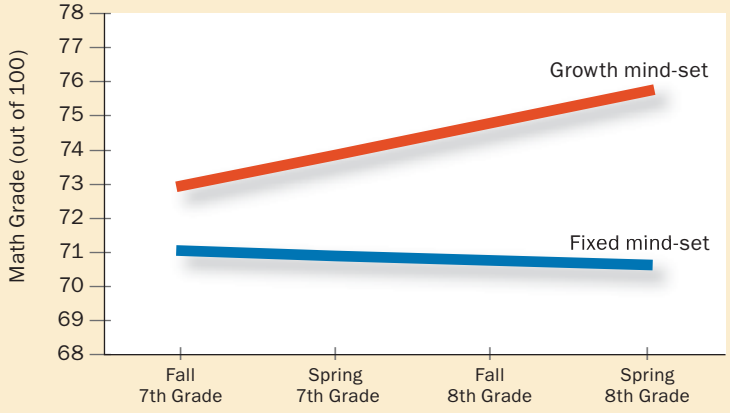
Two Views of Intelligence

Several years later I developed a broader theory of what separates the two general classes of learners—helpless versus mastery-oriented. I realized that these different types of students not only explain their failures differently, but they also hold different "theories" of intelligence. The helpless ones believe that intelligence is a fixed trait: you have only a certain amount, and that's that. I call this a "fixed mind-set." Mistakes crack their self-confidence because they attribute errors to a lack of ability, which they feel powerless to change. They avoid challenges because challenges make mistakes more likely and looking smart less so. Like Jonathan, such children shun effort in the belief that having to work hard means they are dumb.

The mastery-oriented children, on the other hand, think intelligence is malleable and can be developed through education and hard work. They want to learn above all else. After all, if you believe that you can expand your intellectual skills, you want to do just that. Because slipups stem from a lack of effort, not ability, they can be remedied by more effort. Challenges are energizing rather than intimidating; they offer opportunities to learn. Students with such a growth

Mind-set and Math Grades

Students who believed that intelligence is malleable (*growth mind-set line*) earned higher math grades in the fall of seventh grade than those who believed in static intelligence (*fixed mind-set line*), even though the two groups had equivalent math achievement test scores in the sixth grade. The grades of the growth mind-set group then improved over the next two years, whereas the grades of the fixed mind-set students declined.



FROM "IMPLICIT THEORIES OF INTELLIGENCE PREDICT ACHIEVEMENT ACROSS AN ADOLESCENT TRANSITION: A LONGITUDINAL STUDY AND AN INTERVENTION," BY L. S. BLACKWELL, K. H. TRZESNIEWSKI AND C. S. DWECK, IN *CHILD DEVELOPMENT*, VOL. 78, NO. 1; JANUARY/FEBRUARY 2007

A for Effort

According to a survey we conducted in the mid-1990s, 85 percent of parents believed that praising children's ability or intelligence when they perform well is important for making them feel smart. But our work shows that praising a child's intelligence makes a child fragile and defensive. So, too, does generic praise that suggests a stable trait, such as "You are a good artist." Praise is very valuable, however, if it is carefully worded. Praise for the specific process a child used to accomplish something fosters motivation and confidence by focusing children on the actions that lead to success. Such process praise may involve commending effort, strategies, focus, persistence in the face of difficulty, and willingness to take on challenges. Here are some examples:

- You did a good job drawing. I like the detail you added to the people's faces.
- You really studied for your social studies test. You read the material over several times, outlined it and tested yourself on it. It really worked!
- I like the way you tried a lot of different strategies on that math problem until you finally got it.
- That was a hard English assignment, but you stuck with it until you got it done. You stayed at your desk and kept your concentration. That's great!
- I like that you took on that challenging project for your science class. It will take a lot of work—doing the research, designing the apparatus, making the parts and building it. You are going to learn a lot of great things.

Parents and teachers can also teach children to enjoy the process of learning by expressing positive views of challenges, effort and mistakes. Here are examples of such communications:

- Boy, this is hard—this is fun.
- Oh, sorry, that was too easy—no fun. Let's do something more challenging that you can learn from.
- Let's all talk about what we struggled with today and learned from. I'll go first.
- Mistakes are so interesting. Here's a wonderful mistake. Let's see what we can learn from it. —*C.S.D.*

mind-set, we predicted, were destined for greater academic success and were quite likely to outperform their counterparts.

We validated these expectations in a study published in early 2007. Psychologists Lisa Blackwell of Columbia University and Kali H. Trzesniewski of Stanford University and I monitored 373 students for two years during the transition to junior high school, when the work gets more difficult and the grading more stringent, to determine how their mind-sets might affect their math grades. At the beginning of seventh grade, we assessed the students' mind-sets by asking them to agree or disagree with statements such as "Your intelligence is something very basic about you that you can't really change." We then assessed their beliefs about other aspects of learning and looked to see what happened to their grades.

As we had predicted, the students with a growth mind-set felt that learning was a more important goal in school than getting good grades. In addition, they held hard work in high regard, believing that the more you labored at something, the better you would become at it. They understood that even geniuses have to work hard for their great accomplishments. Confronted by a setback such as a disappointing test grade, students with a growth mind-set said they would study harder or try a different strategy for mastering the material.

The students who held a fixed mind-set, however, were concerned about looking smart with little regard for learning. They had negative views of effort, believing that having to work hard at something was a sign of low ability. They thought that a person with talent or intelligence did not need to work hard to do well. Attributing a bad grade to their own lack of ability, those with a fixed mind-set said that they would study *less* in the future, try never to take that subject again and consider cheating on future tests.

AGE FOTOSTOCK

Such divergent outlooks had a dramatic impact on performance. At the start of junior high, the math achievement test scores of the students with a growth mind-set were comparable to those of students who displayed a fixed mind-set. But as the work became more difficult, the students with a growth mind-set showed greater persistence. As a result, their math grades overtook those of the other students by the end of the first semester—and the gap between the two groups continued to widen during the two years we followed them [*see box on page 39*].

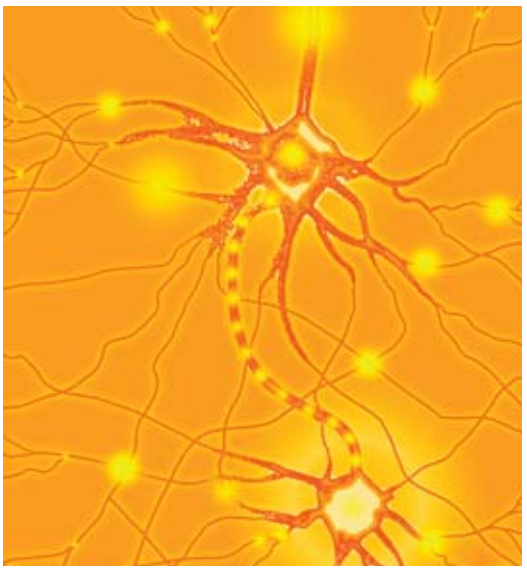
Along with Columbia psychologist Heidi Grant, I found a similar relation between mind-set and achievement in a 2003 study of 128 Columbia freshman premed students who were enrolled in a challenging general chemistry course. Although all the students cared about grades, the ones who earned the best grades were those who placed a high premium on learning rather than on showing that they were smart in chemistry. The focus on learning strategies, effort and persistence paid off for these students.

Confronting Deficiencies

A belief in fixed intelligence also makes people less willing to admit to errors or to confront and remedy their deficiencies in school, at work and in their social relationships. In a study published in 1999 of 168 freshmen entering the University of Hong Kong, where all instruction and coursework are in English, three Hong Kong colleagues and I found that students with a growth mind-set who scored poorly on their English proficiency exam were far more inclined to take a remedial English course than were low-scoring students with a fixed mind-set. The students with a stagnant view of intelligence were presumably unwilling to admit to their deficit and thus passed up the opportunity to correct it.

A fixed mind-set can similarly hamper communication and progress in the workplace by leading managers and employees to discourage or ignore constructive criticism and advice. Research by psychologists Peter Heslin and Don VandeWalle of Southern Methodist University and Gary Latham of the University of Toronto shows that managers who have a fixed mind-set are less likely to seek or welcome feedback from their employees than are managers with a growth mind-set. Presumably, managers with a growth mind-set see themselves as works-in-progress and understand that they need feedback to improve, whereas bosses with a fixed mind-set are more likely to see criticism as reflecting their underlying level of competence. Assuming that other people are not capable of changing either, executives with a fixed mind-set are also less likely to mentor their underlings. But after Heslin, VandeWalle and Latham gave managers a tutorial on the value and principles of the growth mind-set, supervisors became more willing to coach their employees and gave more useful advice.

Mind-set can affect the quality and longevity of personal relationships as well, through people's willingness—or unwillingness—to deal with difficulties. Those with a fixed mind-set are



In tutorials that advance a growth mind-set, students discover that learning promotes the formation of new connections between neurons in the brain.

less likely than those with a growth mind-set to broach problems in their relationships and to try to solve them, according to a 2006 study I conducted with psychologist Lara Kammrath of Wilfrid Laurier University in Ontario. After all, if you think that human personality traits are more or less fixed, relationship repair seems largely futile. Individuals who believe people can change and grow, however, are more confident that confronting concerns in their relationships will lead to resolutions.

Proper Praise

How do we transmit a growth mind-set to our children? One way is by telling stories about achievements that result from hard work. For in-

(The Author)

CAROL S. DWECK is Lewis and Virginia Eaton Professor of Psychology at Stanford University. She has held professorships at Columbia University, the University of Illinois and Harvard University and is a member of the American Academy of Arts and Sciences. Her most recent book is *Mindset,* published by Random House in 2006.

MEHAU KULYK *SPL/Photo Researchers, Inc.*

stance, talking about math geniuses who were more or less born that way puts students in a fixed mind-set, but descriptions of great mathematicians who fell in love with math and developed amazing skills engenders a growth mind-set, our studies have shown. People also communicate mind-sets through praise [*see box on page 40*]. Although many, if not most, parents believe that they should build up a child by telling him or her how brilliant and talented he or she is, our research suggests that this is misguided.

In studies involving several hundred fifth graders published in 1998, for example, Columbia psychologist Claudia M. Mueller and I gave children questions from a nonverbal IQ test. After the first 10 problems, on which most children did fairly well, we praised them. We praised some of them for their intelligence: "Wow … that's a really good score. You must be smart at this." We commended others for their effort: "Wow … that's a really good score. You must have worked really hard."

We found that intelligence praise encouraged a fixed mind-set more often than did pats on the back for effort. Those congratulated for their intelligence, for example, shied away from a challenging assignment—they wanted an easy one instead—far more often than the kids applauded for their effort. (Most of those lauded for their hard work wanted the difficult problem set from which they would learn.) When we gave everyone hard problems anyway, those praised for being smart became discouraged, doubting their ability. And their scores, even on an easier problem set we gave them afterward, declined as compared with their previous results on equivalent problems. In contrast, students praised for their effort did not lose confidence when faced with the harder questions, and their performance improved markedly on the easier problems that followed [*see box on opposite page*].

Making Up Your Mind-set

In addition to encouraging a growth mind-set through praise for effort, parents and teachers can help children by providing explicit instruction regarding the mind as a learning machine. Blackwell, Trzesniewski and I recently designed an eight-session workshop for 91 students whose math grades were declining in their first year of junior high. Forty-eight of the students received instruction in study skills only, whereas the others attended a combination of study skills sessions and classes in which they learned about the growth mind-set and how to apply it to schoolwork.

In the growth mind-set classes, students read and discussed an article entitled "You Can Grow Your Brain." They were taught that the brain is like a muscle that gets stronger with use and that learning prompts neurons in the brain to grow new connections. From such instruction, many students began to see themselves as agents of their own brain development. Students who had been disruptive or bored sat still and took note. One particularly unruly boy looked up during the discussion and said, "You mean I don't have to be dumb?"

As the semester progressed, the math grades of the kids who learned only study skills continued to

Chemist Marie Curie (*left*) and inventor Thomas A. Edison (*right*) developed their genius through passion and tremendous effort.

BETTMANN/CORBIS (*Curie* and *Edison*)

decline, whereas those of the students given the growth-mind-set training stopped falling and began to bounce back to their former levels. Despite being unaware that there were two types of instruction, teachers reported noticing significant motivational changes in 27 percent of the children in the growth mind-set workshop as compared with only 9 percent of students in the control group. One teacher wrote: "Your workshop has already had an effect. L [our unruly male student], who never puts in any extra effort and often doesn't turn in homework on time, actually stayed up late to finish an assignment early so I could review it and give him a chance to revise it. He earned a B+. (He had been getting Cs and lower.)"

Other researchers have replicated our results. Psychologists Catherine Good, then at Columbia, and Joshua Aronson and Michael Inzlicht of New York University reported in 2003 that a growth mind-set workshop raised the math and English achievement test scores of seventh graders. In a 2002 study Aronson, Good (then a graduate student at the University of Texas at Austin) and their colleagues found that college students began to enjoy their schoolwork more, value it more highly and get better grades as a result of training that fostered a growth mind-set.

We have now encapsulated such instruction in an interactive computer program called "Brainology," which should be more widely available by mid-2008. Its six modules teach students about the brain—what it does and how to make it work better. In a virtual brain lab, users can click on brain regions to determine their functions or on nerve endings to see how connections form when people learn. Users can also advise virtual students with problems as a way of practicing how to handle schoolwork difficulties; additionally, users keep an online journal of their study practices.

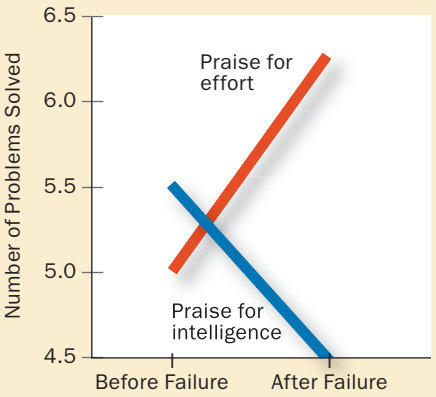
New York City seventh graders who tested a pilot version of Brainology told us that the program had changed their view of learning and how to promote it. One wrote: "My favorite thing from Brainology is the neurons part where when u [sic] learn something there are connections and they keep growing. I always picture them when I'm in school." A teacher said of the students who used the program: "They offer to practice, study, take notes, or pay attention to ensure that connections will be made."

Teaching children such information is not just a ploy to get them to study. People do differ in intelligence, talent and ability. And yet research is converging on the conclusion that great accomplishment, and even what we call genius, is typically the result of years of passion and dedication and not something that flows naturally from a gift. Mozart, Edison, Curie, Darwin and Cézanne were not simply born with talent; they cultivated it through tremendous and sustained effort. Similarly, hard work and discipline contribute much more to school achievement than IQ does.

Such lessons apply to almost every human endeavor. For instance, many young athletes value talent more than hard work and have consequently become unteachable. Similarly, many people accomplish little in their jobs without constant praise and encouragement to maintain their motivation. If we foster a growth mind-set in our homes and schools, however, we will give our children the tools to succeed in their pursuits and to become responsible employees and citizens. M

The Effects of Praise

Children praised for their intelligence solved significantly fewer problems after a failure than they had before encountering difficulty. In contrast, children praised for their effort solved *more* problems after their brush with adversity than they had before it.



(Further Reading)

- **Praise for Intelligence Can Undermine Children's Motivation and Performance.** Claudia M. Mueller and Carol S. Dweck in *Journal of Personality and Social Psychology,* Vol. 75, No. 1, pages 33–52; November 1998.
- **Self-Discipline Outdoes IQ in Predicting Academic Performance of Adolescents.** A. Duckworth and M. Seligman in *Psychological Science,* Vol. 16, pages 939–944; 2005.
- **Why Do Beliefs about Intelligence Influence Learning Success? A Social Cognitive Neuroscience Model.** J. A. Mangels, B. Butterfield, J. Lamb, C. Good and C. S. Dweck in *Social Cognitive and Affective Neuroscience,* Vol. 1, No. 2, pages 75–86; September 2006.
- **The Cambridge Handbook of Expertise and Expert Performance.** Edited by K. A. Ericsson, N. Charness, P. J. Feltovich and R. R. Hoffman. Cambridge University Press, 2006.
- **Implicit Theories of Intelligence Predict Achievement across an Adolescent Transition: A Longitudinal Study and an Intervention.** Lisa S. Blackwell, Kali H. Trzesniewski and Carol S. Dweck in *Child Development,* Vol. 78, No. 1, pages 246–263; January/February 2007.
- **Subtle Linguistic Cues Affect Children's Motivation.** A. Cimpian, H.-M. C. Arce, E. M. Markman and C. S. Dweck in *Psychological Science,* Vol. 18, No. 4, pages 314–316; April 2007.

FROM "PRAISE FOR INTELLIGENCE CAN UNDERMINE CHILDREN'S MOTIVATION AND PERFORMANCE," BY C. M. MUELLER AND C. S. DWECK, IN *JOURNAL OF PERSONALITY AND SOCIAL PSYCHOLOGY*, VOL. 75, NO. 1; JULY 1998

Sex, Math and Scientific Achievement

Why do men dominate the fields of science, engineering and mathematics?

GETTY IMAGES

BY DIANE F. HALPERN, CAMILLA P. BENBOW, DAVID C. GEARY, RUBEN C. GUR, JANET SHIBLEY HYDE AND MORTON ANN GERNSBACHER

For years, blue-ribbon panels of experts have sounded the alarm about a looming shortage of scientists, mathematicians and engineers in the U.S.—making dire predictions of damage to the national economy, threats to security and loss of status in the world. There also seemed to be an attractive solution: coax more women to these traditionally male fields. But there was not much public discussion about the reasons more women are not pursuing careers in these fields until 2005, when then Harvard University president Lawrence Summers offered his personal observations.

He suggested to an audience at a small economics conference near Boston that one of the major reasons women are less likely than men to achieve at the highest levels of scientific work is because fewer females have "innate ability" in these fields. In the wake of reactions to Summers's provocative statement, a national debate erupted over whether

There is **no simple answer** for why there are fewer women than men in some areas of science.

Brains versus brains: Men and women probably have different cognitive strengths as the result of a complex interplay between nature and nurture.

JOSON Getty Images

intrinsic differences between the sexes were responsible for the underrepresentation of women in mathematical and scientific disciplines.

As a group of experts with diverse backgrounds in the area of sex differences, we welcome these ongoing discussions because they are drawing the public's attention to this important issue. In this article, we present an analysis of the large body of research literature pertaining to the question of female participation in these fields, information that is central to understanding sex differences and any proposal designed to attract more women to the science and mathematics workforces. Contrary to the implications drawn from Summers's remarks, there is no single or simple answer for why there are substantially fewer women than men in some areas of science and math. Instead a wide variety of factors that influence career choices can be identified, including cognitive sex differences, education, biological influences, stereotyping, discrimination and societal sex roles.

It does not take a Ph.D. to see how making fuller use of female talent would go a long way toward increasing the number of scientific workers. In the U.S., for example, women made up 46 percent of the workforce in 2003 but represented only 27 percent of those employed in science and engineering. One reason Summers's comment upset many people was its implication that any attempt to close this gap was futile. If most women are naturally deficient in scientific ability, then what could be done? But this

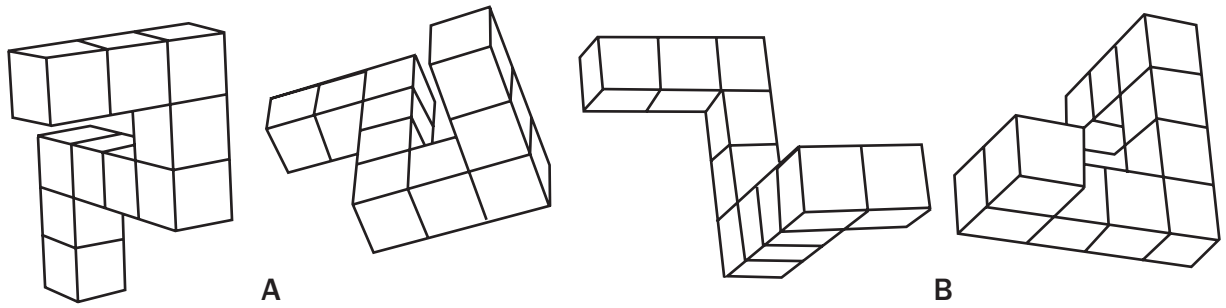
FAST FACTS

Closing the Sex Gap

1» **Women, on average, have stronger verbal skills (especially in writing) and better memory for events, words, objects, faces and activities.**

2» **Men generally are better at mentally manipulating objects and at performing certain quantitative tasks that rely on visual representations.**

3» **Intervention studies are still in their infancy but suggest both sexes can benefit from targeted training to improve their skill set.**



Men generally perform better at "mental rotation" tasks such as this one. The task is to determine if the two figures labeled A and the two figures labeled B could be made identical by rotating them in space.

COURTESY OF DIANE F. HALPERN

seemingly simple interpretation contains two misconceptions.

First, there is no single intellectual capacity that can be called "scientific ability." (For simplicity, we will often use the term "scientific" to refer to skills important to work in the fields of science, technology, engineering and mathematics.) The tools needed for scientific achievement include verbal abilities such as those required to write complex journal articles and communicate well with colleagues; memory skills such as the ability to understand and recall events and complex information; and quantitative abilities in mathematical modeling, statistics, and visualization of objects, data and concepts.

Second, if women and men did demonstrate differences in these talents, this fact would not mean these differences were immutable. Indeed, if training and experience did not make a difference in the development of our academic skills, universities such as Harvard would be accepting tuition from students under false pretenses.

One of the confusing things about the field of sex differences is that you can arrive at very different conclusions depending on how you decide to assess abilities. Women clearly have the right stuff to cut it academically. They have constituted the majority of college enrollments in the U.S. since 1982, with the attendance gap widening every year since then. Similar trends are occurring in many other countries. Furthermore, women receive higher average grades in school in every subject—including mathematics and science.

Despite their success in the classroom, however, women score significantly lower on many standardized tests used for admissions to college and graduate school. The disparity in male-female enrollment in science and related fields grows larger at advanced levels of the education system. For example, in the late 1990s women represented 40 percent of undergraduates in science at the Massachusetts Institute of Technology but only 8 percent of the faculty.

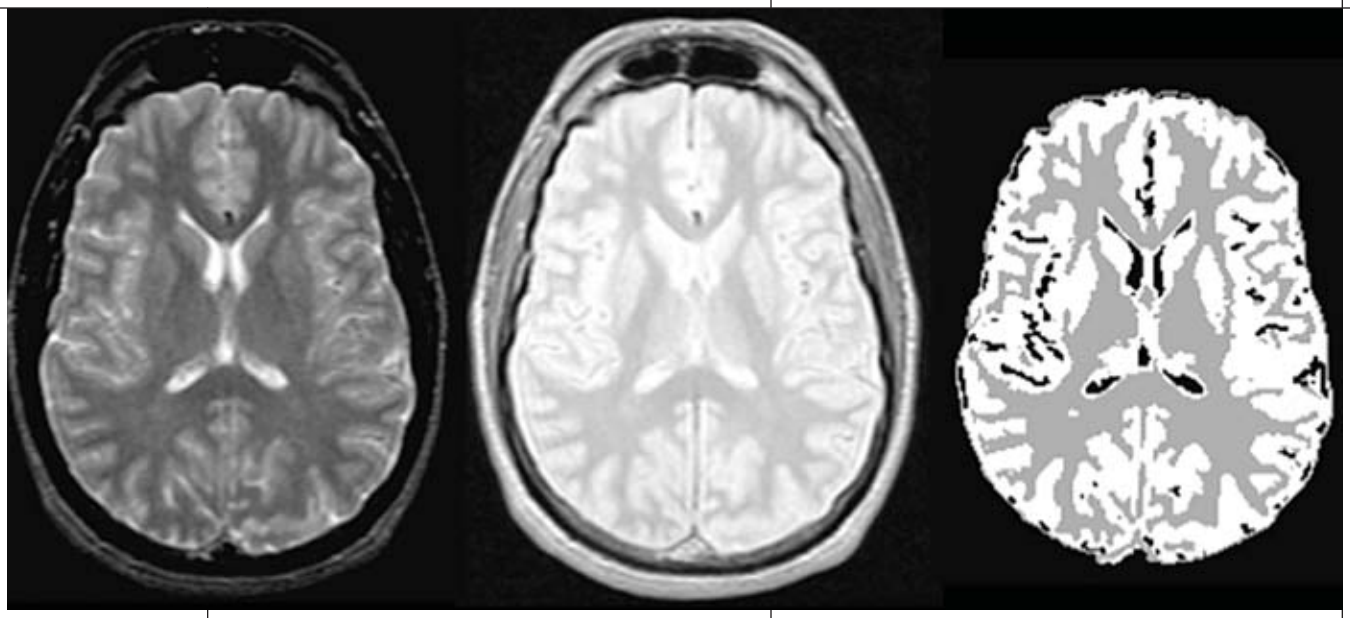
Defining Sex Differences

Because grades and overall test scores depend on many factors, psychologists have turned to assessing better-defined cognitive skills to understand these sex differences. Preschool children seem to start out more or less even, because girls and boys, on average, perform equally well in early cognitive skills that relate to quantitative thinking and knowledge of objects in the surrounding environment.

Around the time school begins, however, the sexes start to diverge. By the end of grade school and beyond, females perform better on most assessments of verbal abilities. In a 1995 review of the vast literature on writing skills, University of Chicago researchers Larry Hedges (now at Northwestern University) and Amy Nowell put it this way: "The large sex differences in writing … are alarming. The data imply that males are, on average, at a rather profound disadvantage in the performance of this basic skill." There is also a female advantage in memory of faces and in episodic memory—memory for events that are personally experienced and are recalled along with information about each event's time and place.

There is another type of ability, however, in which boys have the upper hand, a skill set referred to as visuospatial: an ability to mentally navigate and model movement of objects in three dimensions. Between the ages of four and five, boys are measurably better at solving mazes on standardized tests. Another manifestation of visuospatial skill in which boys excel involves "mental rotation," holding a three-dimensional object in memory while simultaneously transforming it [*see illustration above*]. As might be expected, these capabilities also give boys an edge in solving math problems that rely on creating a mental image.

Indeed, of all the sex differences in cognitive abilities, variation in quantitative aptitude has received the most media attention. This popular



Sexing the brain: A variety of brain-imaging techniques have allowed researchers to find differences in the structure and function of female and male brains.

fascination is, in part, because mastery of these skills is a prerequisite for mathematically intensive disciplines such as physics and engineering. And, as Summers suggested, if women were disadvantaged in these skills, it would go a long way to explaining why women are typically underrepresented in these fields. But the data are much less clear-cut.

As we said before, females get higher grades in math classes at all grade levels and also do slightly better on international assessments in algebra, perhaps because of its languagelike structure. But boys shine on the math part of the Scholastic Aptitude Test (SAT)—resulting in a difference of about 40 points that has been maintained for over 35 years. When all the data on quantitative ability are assessed together, however, the difference in average quantitative ability between girls and boys is actually quite small. What sets boys apart is that many more of them are mathematically gifted.

At first, this statement seems almost paradoxical. If boys and girls are, on average, equally skilled at math, how could there be greater numbers of gifted boys? For reasons that are not yet fully understood, it turns out that males are much more variable in their mathematical ability, meaning that females of any age are more clustered toward the center of the distribution of skills and males are spread out toward the ends. As a result, men outnumber women at the very high—and very low—ends of the distribution. Data from the Study of Mathematically Precocious Youth exemplify this phenomenon. In the 1980s one of us (Benbow), along with the late psychologist Julian C. Stanley, who founded this study at the John Hopkins University Center for Talented Youth, observed sex differences in mathematical reasoning ability among tens of thousands of intellectually talented 12- to 14-year-olds who had taken the SAT several years before the typical age.

Among this elite group, no significant differences were found on the verbal part of the SAT, but the math part revealed sex differences favoring boys. There were twice as many boys as girls with math scores of 500 or higher (out of a possible score of 800), four times as many boys with scores of at least 600, and 13 times as many boys with scores of at least 700 (putting these test takers in the top 0.01 percent of 12- to 14-year-olds nationwide).

Although it has drawn little media coverage, dramatic changes have been occurring among these junior math wizards: the relative number of girls among them has been soaring. The ratio of boys to girls, first observed at 13 to 1 in the 1980s, has been dropping steadily and is now only about 3 to 1. During the same period the number of women in a few other scientific fields has surged. In the U.S., women now make up half of new medical school graduates and 75 percent of recent veterinary school graduates. We cannot identify any single cause for the increase in the number of women entering these formerly male-dominated fields, because multiple changes have occurred in society over the past several decades.

This period coincides with a trend of special programs and mentoring to encourage girls to take higher-level math and science courses. And direct evidence exists that specifically targeted training could boost female performance even further. A special course created by engineering professor Sheryl A. Sorby and mathematics edu-

FROM *JOURNAL OF NEUROSCIENCE*, VOL. 19, NO. 10; MAY 15, 1999; COURTESY OF RUBEN C. GUR

cation specialist Beverly J. Baartmans at Michigan Technological University, for example, targeted improvement in visuospatial skills. All first-year engineering students with low scores on a test of this ability were encouraged to enroll in the course. This enrollment resulted in improved performance in subsequent graphics courses by these students and better retention in engineering programs, which suggests that the effects persisted over time and were of at least some practical significance for both women and men.

The Role of Biology

Decades of data from studies of different animal species show that hormones can play a role in determining the cognitive abilities that males and females develop. For example, during typical prenatal male development, high levels of hormones such as testosterone masculinize the developing brain and result in male-typical behaviors and probably male patterns of cognitive performance.

More recent studies have shown that hormones continue to play a role in cognitive development throughout life. Such changes have been observed in individuals receiving large quantities of male or female hormones in preparation for sex-change surgery. Researchers found, for example, that people undergoing female-to-male hormone treatment show "masculine" changes in their cognitive patterns: improvements in visuospatial processing and decrements in verbal skills.

The human brain is shaped by these hormones, as well as by our genetic inheritance and a lifetime of experiences, so it should not be surprising that numerous differences appear in female and male brains. In general, females have a higher percentage of gray matter brain tissue, areas with closely packed neurons and fast blood flow, whereas males have a higher volume of connecting white matter tissue, nerve fibers that are insulated by a white fatty protein called myelin. Furthermore, men tend to have a higher percentage of gray matter in the left hemisphere, whereas no such asymmetries are significant in females.

Imaging studies assessing brain function support the notion that females perform better on tasks such as language processing that call on more symmetric activation of brain hemispheres, whereas males excel in tasks requiring activation of the visual cortex. Even when men and women perform the same task equally well, studies suggest they sometimes use different parts of their brain to accomplish it.

It is important to emphasize, though, that finding sex differences in brain structures and functions does not suggest these are the sole cause of observed cognitive differences between males and females. Because the brain reflects learning and other experiences, it is possible that sex differences in the brain are influenced by the differences in life experiences that are typical for women and men.

What leads **one little Einstein** to choose electrical engineering and the other law?

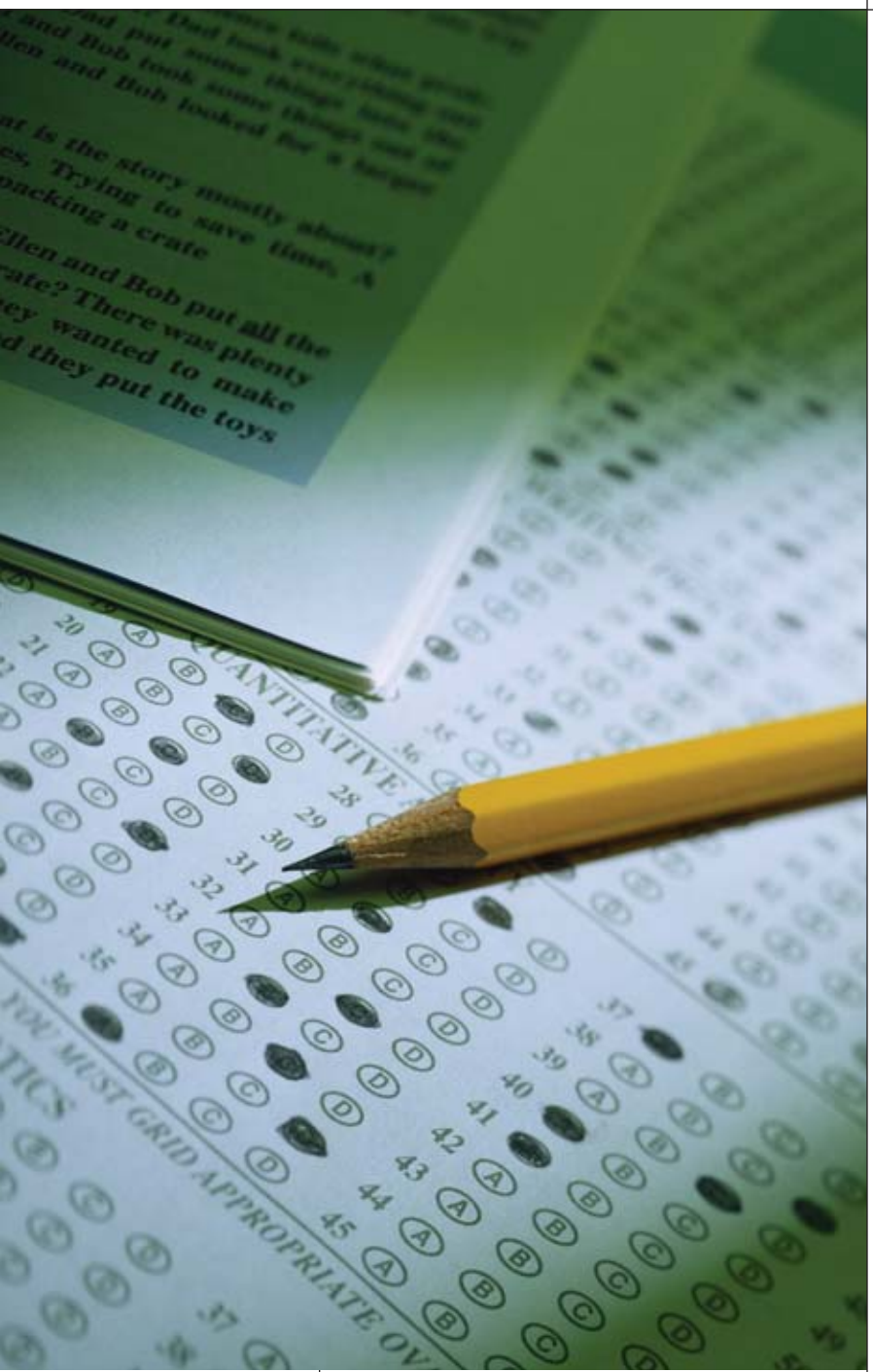
Ladies' Choice

Of course, even if you're smart, you might not want to be a scientist. Studies of mathematically gifted youth are of special interest to understanding the psychology of career choice because, within this sample, there is little doubt that each boy and girl has the capacity to excel in science. What leads one little Einstein to choose electrical engineering and the other law? A 10-year study of 320 profoundly gifted individuals (top one in 10,000) found that those whose mathematical skills were stronger than their verbal ones (even though they had very high verbal ability) said math and science courses were their favorites and were very likely to pursue degrees in those areas. On the other hand, those kids whose verbal skills were even higher than their math skills said humanities courses were their favorites and most often pursued educational credentials in the humanities and law.

It appears then that highly gifted kids ask themselves, "What am I better at?" rather than

(The Authors)

DIANE F. HALPERN is a psychologist at Claremont McKenna College. **CAMILLA P. BENBOW** is dean of education and human development at Vanderbilt University. **DAVID C. GEARY** is a psychologist at the University of Missouri. **RUBEN C. GUR** is a psychologist at the University of Pennsylvania. **JANET SHIBLEY HYDE** and **MORTON ANN GERNSBACHER** are psychologists at the University of Wisconsin–Madison.



Most standardized math tests—such as those of the SAT college admission test—favor male students, even though women receive higher average grades in college math classes.

AGE FOTOSTOCK

"Am I smart enough to succeed in a particular career?" This finding provides some insight into sex differences. Among precocious children, boys more frequently exhibit a "tilt" favoring mathematical and related abilities compared with verbal aptitude. Encouraging more balanced gifted students to keep science and technology fields open as options may help top off the pipeline with more high-achieving female and male students.

It is true that multiple psychological and social factors play a part in determining career direction. People's individual expectations for success are shaped by their perception of their own skills. One factor in forming our self-perception is how authority figures such as teachers and parents perceive and respond to us. A 1992 study by psychology professors Lee Jussim of Rutgers University and Jacquelynne Eccles of the University of Michigan at Ann Arbor found that the level at which teachers rated a student's mathematical talent early in the school year predicted later test scores—even when objective measures of ability were at odds with the teacher's perception. This study and others suggest that stereotypes of science as masculine may prejudice educators against girls from the start.

The Enduring Glass Ceiling

Perhaps most troubling is the thought that a skilled, confident scientist could climb to the top and still face discrimination when she gets there. Nevertheless, plenty of research suggests that people's perception of a job as stereotypically masculine or feminine results in a bias in hiring and compensating candidates or employees who are male and female, respectively. Even though social psychologists agree that the overt sexism that existed decades ago in the U.S. and in many other countries is now rare, they say it has been replaced by unconscious sexism in some situations.

The real-world impact of covert biases on female achievement in science is not well studied because of the shroud of secrecy surrounding peer review, the process by which many aspects of a scientist's career—awarding of grants, acceptance of academic papers for publication and decisions about hiring—are judged by a panel of other, often anonymous, scientists.

There has been one thorough study of the real-world peer-review process. Biologists Christine Wenneras and Agnes Wold of Goeteborg University gained access to the Swedish Medical Research Council's data on postdoctoral fellowship awards only after a battle in court. Shortly before the investigators published their study in 1997, the United Nations had named Sweden the leading country in the world with respect to equal opportunities for men and women. Even so, men dominated Swedish science. At the time, women received 44 percent of Swedish biomedical doctoral degrees but held only 25 percent of postdoctoral positions and 7 percent of professional positions.

What Wenneras and Wold discovered was

Women work **fewer hours per week** and spend more time on family and household tasks than comparably educated men do.

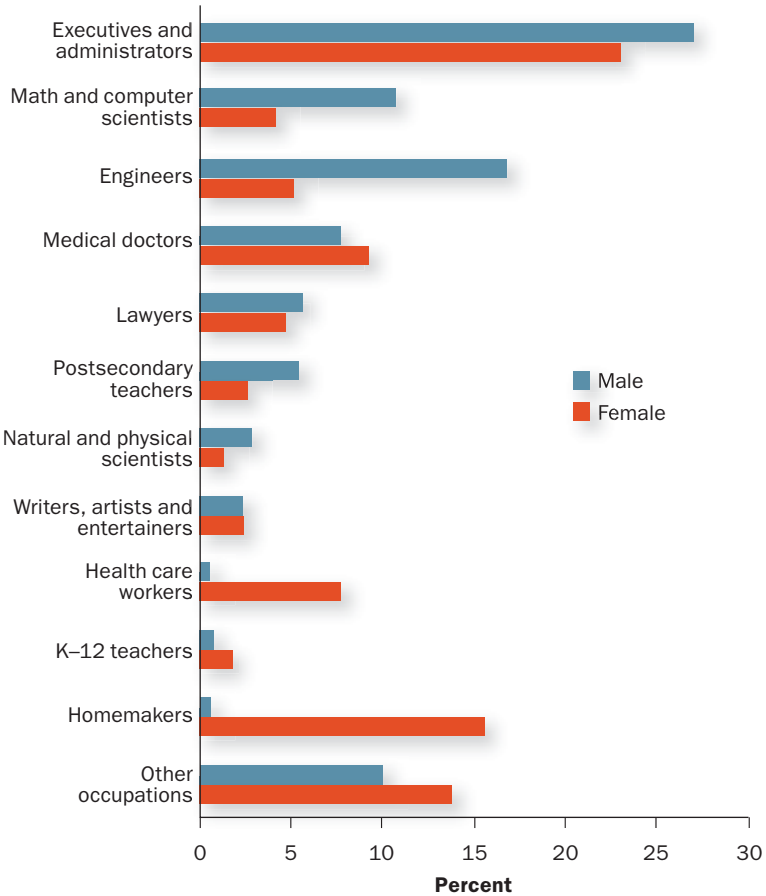
shocking. Female applicants received lower mean scores in all areas in which they were evaluated: scientific competence, quality of proposed methodology and relevance of the research proposal. It was possible that the women applicants were less qualified. To test this possibility, the investigators computed scientific productivity based on the applicant's total number of publications, number of first-author publications, quality of each publication and number of times other scientific papers cited their work. By these measures, the *most* productive group of female researchers was rated as comparable in ability to the *least* productive male researchers. All other women were rated below all the men. The authors of this study concluded that the peer-review process in what is arguably the most gender-equal nation in the world is rife with sexism. These results provide a strong rationale for making the peer-review process more transparent. Despite these findings, which were published in the top-ranked international scientific journal *Nature*, there has been no progress toward making the peer-review process more open.

Finally, we cannot consider success at work without considering the effort needed for families to function and maintain a home. Even when husbands and wives both work full-time, women continue to assume most of the child care duties and to shoulder most of the responsibility for tending to sick and elderly family members. Women work, on average, fewer hours per week and spend more time on family and household tasks than comparably educated men do. For women, having children is associated with lower income and a reduced probability of attaining tenure. In contrast, men show a slight tendency to benefit professionally when they become fathers. Thus, the different roles women and men play in family care can also explain their differential participation in demanding careers.

Where We Go from Here

If Larry Summers's comments had one appealing feature, it was the benefit of simplicity. If the lack of women in science were a reflection, in part, of lack of ability, then the take-home lesson would seem to be that we can do nothing but accept the natural order of things.

As this article shows, however, the truth is not so simple. Both sexes, on average, have their strengths and weaknesses. Nevertheless, the research argues much could be done to try to help more women—and men for that matter—excel in science and coax them to choose it as a profession. The challenges are many, requiring innovations in education, targeted mentoring and career guidance, and a commitment to uncover and root out bias, discrimination and inequality. In the end, tackling these issues will benefit women, men and science itself. M

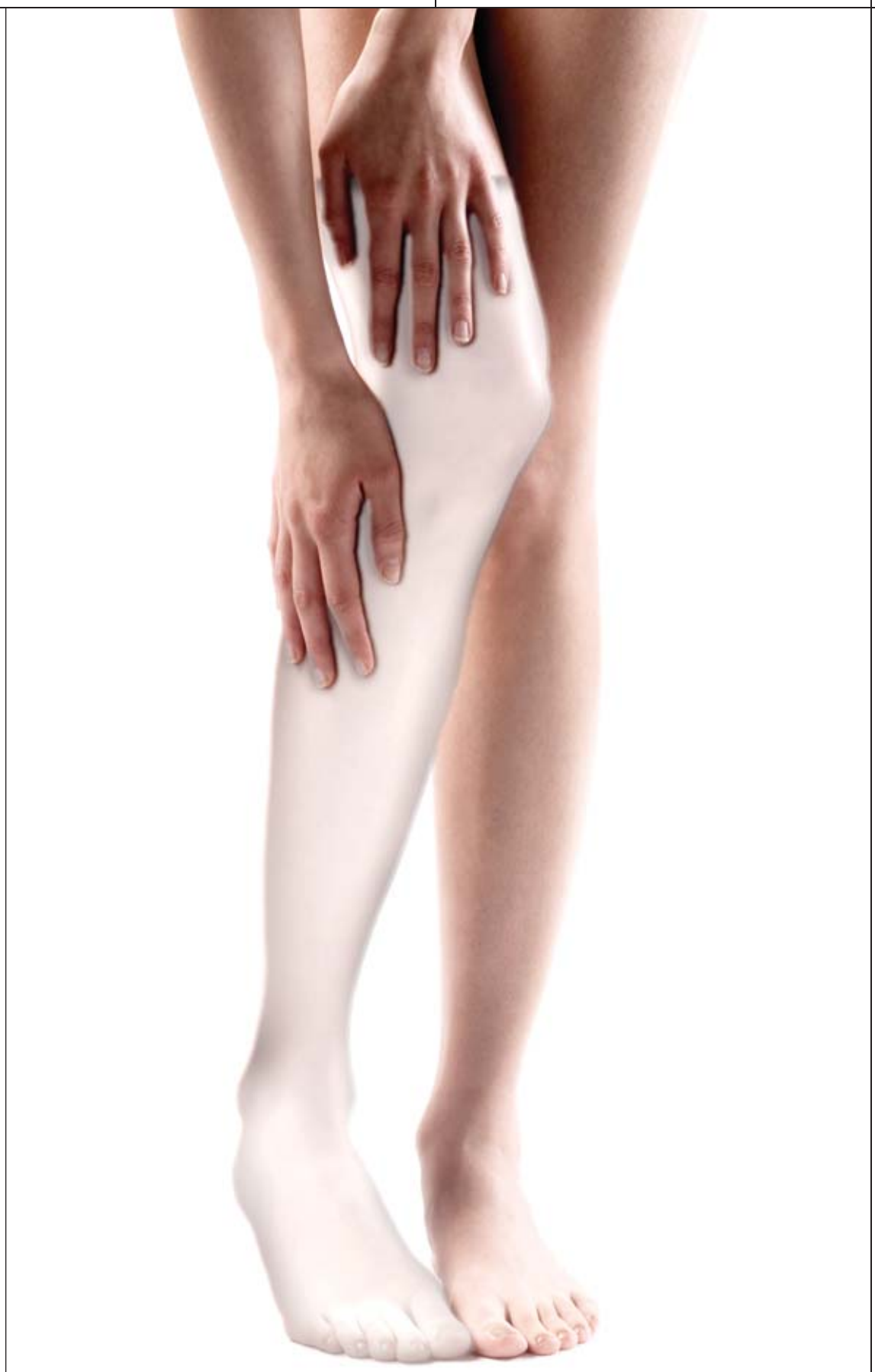


Sex differences in career choice are apparent even among mathematically gifted children. The graph shows a study on the eventual career choice of boys and girls who ranked in the top 1 percent in mathematical ability.

SOURCE: "SEX DIFFERENCES IN MATHEMATICAL REASONING ABILITY AT AGE 13: THEIR STATUS 20 YEARS LATER," BY C. P. BENBOW, D. LUBINSKI, D. L. SHEA AND H. EFTEKHARI-SANJANI IN *PSYCHOLOGICAL SCIENCE*, VOL. 11, NO. 6, 2000

(Further Reading)

- **The Science of Sex Differences in Science and Mathematics.** Diane F. Halpern, Camilla P. Benbow, David C. Geary, Ruben C. Gur, Janet Shibley Hyde and Morton Ann Gernsbacher in *Psychological Science in the Public Interest*, Vol. 8, No. 1, pages 1–51; August 2007.



GETTY IMAGES

Living with *Ghostly* Limbs

Scientists are pinpointing the neurological roots of the vivid and painful illusion of phantom limbs in amputees—and finding ways to curb it

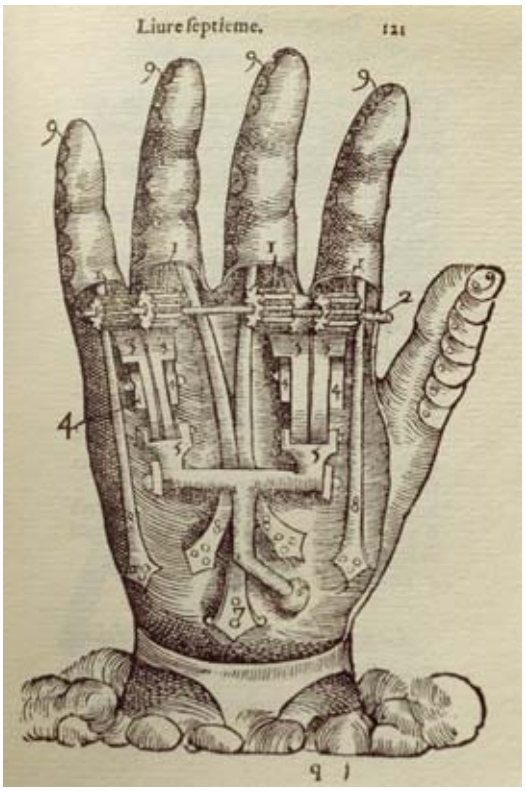
By Miguel Nicolelis

One morning in my fourth year of medical school, a vascular surgeon at the University Hospital in São Paulo, Brazil, invited me to visit the orthopedics inpatient ward. "Today we will talk to a ghost," the doctor said. "Do not get frightened. Try to stay calm. The patient has not accepted what has happened yet, and he is very shaken."

A boy around 12 years old with hazy blue eyes and blond curly hair sat before me. Drops of sweat soaked his face, contorted in an expression of horror. The child's body, which I now watched closely, writhed from pain of uncertain origin. "It really hurts, doctor; it burns. It seems as if something is crushing my leg," he said. I felt a lump in my throat, slowly strangling me. "Where does it hurt?" I asked. He replied: "In my left foot, my calf, the whole leg, everywhere below my knee!"

As I lifted the sheets that covered the boy, I was stunned to find that his left leg was half-missing; it had been amputated right below the knee after being run over by a car. I suddenly realized that the child's pain came from a part of his body that no longer existed. Outside the ward I heard the surgeon saying, "It was not him speaking; it was his phantom limb."

At that time, I did not know that at least 90 percent of amputees—millions worldwide—have experienced a phantom limb: the strange and errant feeling that a missing body part is still present and attached to their body. In some cases, the part moves; in others, it is locked in place. Such ghostly appendages are often defined by a diffuse tingling sensation that extends throughout the amputated limb



Artificial articulated hand designed by French military surgeon Ambroise Paré, who described many cases of phantom limbs in soldiers returning from European battlefields in the 1500s. His work was ignored for more than 300 years.

and effectively reconstructs it. These phantoms are often very painful and terrifyingly vivid. In some cases, they endure for years.

Although scientists are still struggling to identify the biological basis for such apparitions, recent research suggests that they are not the product of erroneous neural signals emanating from an amputee's stump. Rather, most neuroscientists now believe, they arise largely from activity in networks of neurons distributed throughout the brain. These networks enable a person to create an anatomical image of his or her own body and attach sensations to that body image. Studies of such cerebral representations and how they change after amputation have led to new experimental therapies for phantom limb syndrome.

FAST FACTS

Anatomical Apparitions

1» At least 90 percent of amputees have had a phantom limb: they perceive that a missing body part is still present and attached to their body. Such phantoms are often very painful and may persist for years.

2» Recent studies suggest that phantom limbs are not the product of erroneous neural signals emanating from an amputee's stump. Rather they are now thought to arise largely from activity in neural networks in the brain that build a mental image of the body.

3» Researchers are trying to treat phantom limb syndrome using mirrors and virtual reality, both of which create illusions that can help patients gain better control over their ghostly appendages and may help decrease phantom pain.

Painful Appendages

Scientists, doctors and laypeople have known about phantom limbs for centuries. During the Middle Ages, for instance, European folklore glorified the miraculous restoration of sensation in amputated limbs in soldiers.

In one account, which dates back to the fourth century, twin boys tried to physically reattach limbs onto patients who had lost an arm or leg. The amputees supposedly developed the feeling of the divine presence in the missing part of their body—presumably the result of a phantom. The boys later became official saints of the Catholic Church; amputees who prayed to their memory felt their limbs coming back. In the 1500s French military surgeon Ambroise Paré, whose improved surgical techniques boosted survival for amputees, described many cases of the phenomenon in soldiers returning from European battlefields.

In 1872 American neurologist Silas Weir Mitchell coined the term "phantom limb" to describe the sensations that mutilated Civil War soldiers felt in their lost limbs. Since then, scientists have written up hundreds of case studies, revealing various manifestations. Interviews with amputees suggest that intense limb pain before amputation, say, from a severe fracture, deep ulcer, burn or gangrene, is a major risk factor for developing phantom pain afterward—as if the pain were etched in memory so that it remains even after its source is gone. More than 70 percent of patients find their phantom limbs painful immediately after surgery; in many cases, the pain persists for years.

Phantom limbs sometimes perform phantom movements. Recent amputees may even wake up screaming that their nonexistent leg is "trying to leave the bed on its own to walk around the room." In one third of afflicted people, however, the absent limb becomes completely paralyzed, often agonizingly so—for instance, embedded in an ice cube, permanently twisted in a spiral or tortuously pinned to the back.

Researchers now know that phantom sensa-

ERIC PREAU *Sygma/Corbis*

Phantom limbs sometimes perform phantom movements—but in other cases they are paralyzed.

BETTMANN/CORBIS

Armory Square Hospital, Washington, D.C., 1865. American neurologist Silas Weir Mitchell coined the term "phantom limb" to describe the sensations that Civil War soldiers felt in their lost limbs.

tions can occur in any excised body part, not just the arms and legs; people who have lost their breasts, teeth, genitals and even internal organs have had them. Women with hysterectomies, for example, have felt illusory menstrual pain and laborlike uterine contractions.

Pain from phantom limbs can also be very debilitating. Amputees with such pain are much less likely to use a prosthetic limb, studies have shown, restricting their ability to care for themselves, visit friends and engage in other activities. And unfortunately, only a tiny fraction of such patients find relief from the dozens of available pain therapies.

Blaming the Brain

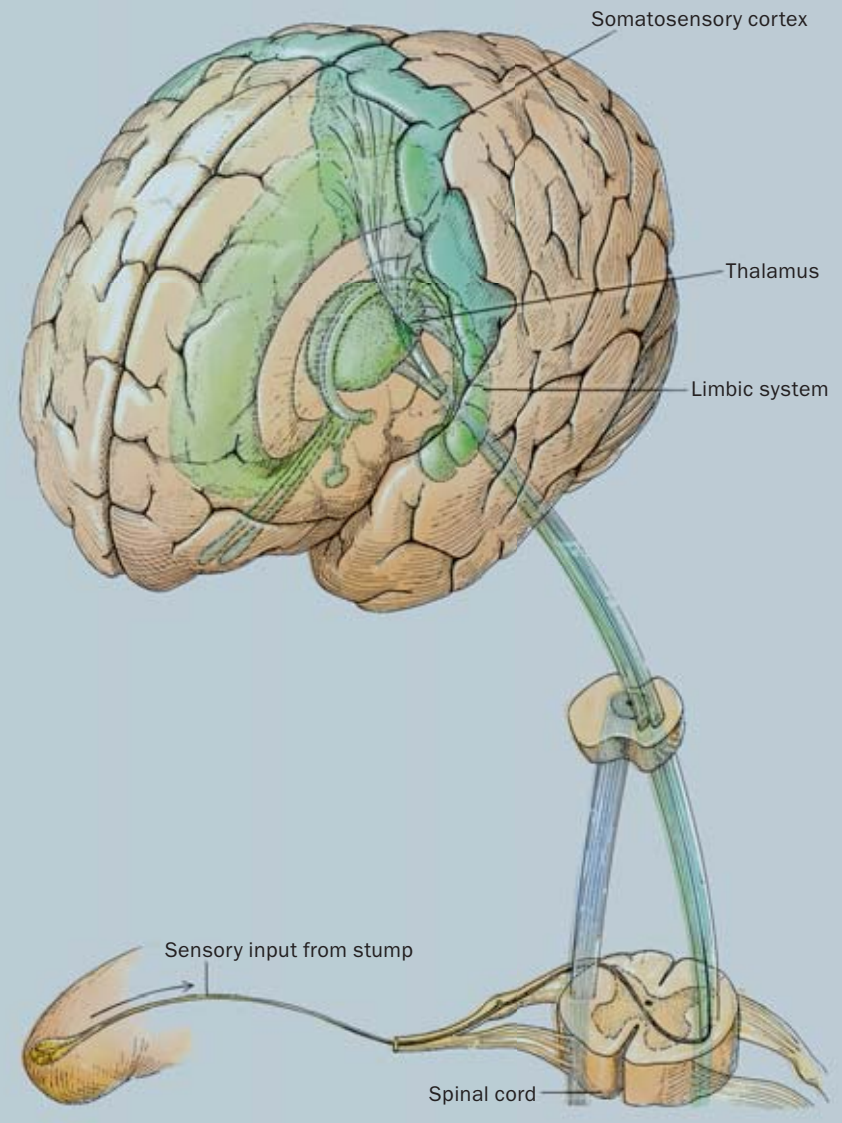
Despite decades of investigation, scientists have not pinned down the biological origins of this disturbing illusion. An early notion, put forth during the second half of the 20th century, came from the late neuroscientist Patrick Wall, then at University College London. Wall placed blame for the phantom limb phenomenon on the severed nerve fibers in the scarred region of the amputee's stump. These fibers form nodules, or neuromas, which were thought to send erroneous signals through the spinal cord to the brain that might be misinterpreted as tingling or pain in the absent limb.

When doctors attempted to treat phantom limb sensations by cutting the sensory nerves leading to the spinal cord, severing nerves in the cord, or even removing parts of the brain that receive the sensory neuronal tracts, the phantoms nonetheless persisted. Sometimes the patients' pain temporarily vanished but then returned. Thus, many researchers rejected the idea that problems with the peripheral nerves could fully account for the syndrome.

In the late 1980s psychologist Ronald Melzack of McGill University and his colleagues put forth the alternative notion that illusory body parts arise at least in part from neural activity within the brain. Such a view echoed earlier writings from naturalist Erasmus Darwin, an 18th-century British intellectual and grandfather to Charles Darwin, who once penned: "Does it not seem clear that such a [phantom]

The Body in the Brain

The brain not only receives sensory signals from various parts of the body, but it is thought to generate its own pattern of neural activity that represents the body in its intact state. The brain's somatosensory cortex contains a map of various body regions; it receives tactile information from the body via a sensory pathway that traverses the thalamus. Another neural conduit transmits information from the body to the limbic system, which governs emotions such as those associated with phantom limbs. After the loss of a body part, activity in this neural system may result in the perception of a phantom limb.



CAROL DONNER

phenomenon indicates that our ideas and sensations emerge from our brains, and not from our tactile organs?"

In Melzack's view, the brain not only detects sensory signals from the body but also generates its own neural pattern, or neural signature, that represents the body in its intact state. This signature inscribes the psyche with a sense of the body's configuration and borders—and of the body belonging to an individual. It persists even after the removal of a body part, creating the mistaken perception that the part is still present and attached to the body.

Orchestrating such a neural signature, the theory goes, falls to a large network of neurons that Melzack termed the "neuromatrix." The

The brain can create a **neural picture** of the human physique even without sensory signals from the body.

neuromatrix includes the somatosensory cortex at the brain's surface on the top of the head and other regions of the parietal lobe (a quadrant of the brain beneath the top and back of the head) that construct a person's body image and his or her sense of self. In addition, it consists of two neural pathways: the sensory pathway that conveys tactile information through the thalamus—a sensory relay station deep in the brain—to the somatosensory cortex and another that traverses the brain's limbic system, a group of buried brain structures that govern emotions such as those associated with phantom limbs [*see box on opposite page*].

Consistent with such a theory, damage to part of this neuromatrix can result in the loss of ownership of part or all of one's body. (It might also result in body integrity identity disorder [see "Amputee Envy," by Sabine Mueller, on page 60].) Injuries to the right parietal lobe caused by brain trauma or stroke can lead to left hemibody neglect syndrome, in which patients become indifferent to the entire left side of their body. Such patients may, for example, fail to put on the left sleeve of a shirt or a left shoe. When asked about such behavior, these individuals typically deny that the left arm or leg is theirs; the counterpart to the right side of their body, they assert, belongs to someone else.

The effect can be transient in some cases—and very strange. In one instance described to me, a NASA astronaut piloting his first space mission told his colleagues during the initial orbit to "stop poking their hands in his left control panel." His crew informed him that the hand in question was his own, but the pilot denied it, declaring that "the hand in the left panel is certainly not mine." A few hours later, to the relief of the crew (and Houston), the pilot suddenly said, "Just relax, guys. I have found my missing left hand on the control panel!" Presumably, the spacecraft's acceleration during liftoff or the lack of gravity temporarily deprived the pilot's right parietal lobe of blood, producing a fleeting form of left hemibody neglect syndrome.

Modifying the Matrix

The basic structure of our neuromatrix may be present at birth, its blueprint likely inscribed in our genes, Melzack proposes. Such a congenital network would explain why, as Melzack and his colleagues reported in 1997, phantom arms or legs often appear in children born without these body parts. Melzack's team found phantoms in 41 of 125 people who were either born without a limb or had one amputated before age six, indicating that such anatomical ghosts occur in about a fifth of people missing a limb at birth and more than half of amputees who are young children. Thus, the human brain seems able to generate a neural picture of the complete human physique even in the absence of sensory signals from the body.

Nevertheless, gross changes in body structure after birth—and, consequently, neural input to the neuromatrix—can provoke changes in this brain network, some of which may buttress the brain's role in creating phantom limbs. The somatosensory cortex in the parietal lobe contains neurons that receive input from, and so are thought to produce a conscious sense of, the various body parts.

COURTESY OF VILAYANUR S. RAMACHANDRAN

A vertical mirror reflecting the image of an intact limb can create the illusion that a phantom limb has been resurrected and can be controlled. Exercises using such a mirror have relieved phantom limb spasms and pain in a small number of amputees.

(The Author)

MIGUEL NICOLELIS is a professor of neurobiology and biomedical engineering at Duke University and coordinator of the Edmond and Lily Safra International Institute of Neurosciences of Natal in Brazil. He also lectures at the Swiss Federal Institute of Technology in Lausanne, Switzerland. He holds an M.D. and a Ph.D. from the University of São Paulo.

An amputee immerses himself in a three-dimensional virtual reality in which his real limb movements are transposed onto a virtual limb that serves as a stand-in for his phantom limb. In this world, users transfer feelings from their real limb to the muscles and joints of the phantom. A preliminary study suggests that the illusion can result in partial relief of phantom pain.

These neurons are arranged in a topographical map. Experiments conducted in the 1980s by neuroscientists Jon Kaas of Vanderbilt University and Michael Merzenich of the University of California, San Francisco, and their colleagues, among others, have shown that amputation causes a restructuring of this body map such that the cerebral neurons that represented the excised part switch their allegiance to adjacent body regions. Merzenich's team, for example, found that amputation of a monkey's middle finger caused the brain cells that previously responded only to stimulation of that finger to respond instead to stimulation of the index and ring fingers within a matter of months.

In 1993 John Chapin and I showed that this reorganization process started immediately after blocking impulses from sensory nerves in the whiskers of rats and that it occurred in the thalamus, among other deeper brain structures, as well as the somatosensory cortex. The late neuroscientist Tim Pons, then at the National Institute of Mental Health, and his co-workers extended this idea. Cutting off sensory input from a monkey's entire arm, they found, prompted a more widespread reorganization in which the neurons once assigned to the hand switched to react to signals from the face, which is represented next to the arm in the brain's map. In 1998 they reported a similar reorganization in the thalamus and brain stem relays of the somatosensory system.

Such revamping also occurs in the human cerebral cortex after an arm amputation, according to work by neuroscientist Vilayanur S. Ramachandran of the University of California, San Diego, and his colleagues. Using an imaging technique called magnetoencephalography, which measures the magnetic fields produced by electrical activity in the brain, the researchers showed in the early 1990s that sensory input from the face activated the hand area in the brain's cerebral body map.

When Ramachandran's team touched the faces of amputees in particular locations, the researchers found that the sensory nerve signals, now traveling to the hand area of the somatosensory cortex, evoked feelings in their phantom hand. Moreover, the researchers found that the lower face region contains an organized map of the hand such that tactile stimulation of specific points on the face elicits sensations from specific points on the phantom hand. The type of sensation—whether hot, cold, rubbing or massage—is the same in both locations.

Other efforts have since linked such brain reorganization to phantom limb pain. In a 1995 study neuroscientist Herta Flor of the University of Heidelberg in Germany and her colleagues used noninvasive neuromagnetic techniques to detect the degree of cortical reorganization in 20 amputees. They found a strong relation between the amount of neural restructuring and the magnitude of phantom arm pain, suggesting that the pain may result from such changes in the somatosensory cortex.

A follow-up 2001 study led by psychologist Niels Birbaumer of the University of Tuebingen in Germany lends further support to this idea. The scientists, who included Flor, used a brain-imaging technique called functional magnetic resonance imaging to show that imagined movement of the phantom hand activated the face area of the somatosensory cortex in patients with phantom limb pain, but not in pain-free amputees. The researchers hypothesize that phantom limb pain results from the simultaneous activation of the hand and mouth regions of the brain's body map.

Ghost Busters

Ramachandran and his wife, neuroscientist Diane Rogers-Ramachandran, have since developed a possible treatment for phantom limb syn-

COURTESY OF STEVE PETTIFER

Researchers are trying to ameliorate phantom limb pain using computer simulations of the body.

drome based on the malleability of the brain's body maps. The researchers removed the top of a cardboard box and inserted a vertical mirror. Ten arm amputees inserted their intact arm in the front of the box so that the arm's reflection in the mirror overlay the perceived location of the phantom limb. This created a visual illusion that the phantom arm had been resurrected. When each patient moved his real arm, he could see that his "phantom" arm was obeying his motor commands [see "It's All Done with Mirrors," by Vilayanur S. Ramachandran and Diane Rogers-Ramachandran; Scientific American Mind, August/September 2007].

Six of the patients who used the mirror box said they could feel as well as see their phantom moving, generating the impression that both arms could now be moved. Four of the patients used this newfound ability to relax and open a clenched phantom hand, which provided relief from painful spasms. Three weeks of daily practice with the mirror caused one patient's phantom arm to largely disappear. And when most of the limb vanished, so did the pain from the phantom elbow. The visual illusion apparently corrected the tactile one, suggesting that the activity of central visual circuits can modify the activity of the proposed neuromatrix, the researchers reported in 1996.

A decade later psychologist Eric Brodie of Glasgow Caledonian University in Scotland and his colleagues reported hints of success in a test of a mirror box modified for a leg. Forty-one lower-limb amputees watched a reflection of their intact leg in the mirror as they moved this leg and tried to move their phantom leg. Another 39 amputees tried to move both their phantom and real legs without the mirror. Both efforts, which involved 10 different movements each repeated 10 times, diminished phantom limb sensations, including pain. Although the mirror did not enhance this effect, it did produce significantly more phantom limb movements and more vivid awareness of the phantom leg than did the exercise without the mirror. Prolonged mirror treatment might be more effective in fighting phantom pain, the researchers propose, perhaps by reversing the ongoing reorganization of the brain thought to be responsible for phantom limb pain.

Researchers are now trying to ameliorate phantom limb pain with immersive three-dimensional computer simulations—so-called virtual reality (VR)—that can produce illusions similar to those created by the mirror. The technology can display a patient's entire body, including his or her phantom limb, and enable the patient to perform complex movements of the fingers, toes, hands, feet, arms and legs that are not possible with mirror therapy. In a preliminary 2007 study psychologist Craig Murray and his colleagues at the University of Manchester in England exposed two upper-limb amputees and one lower-limb amputee to a simulation that transported a user's limb movements to those of a virtual limb, which overlay their phantom limb in the virtual environment. All three amputees, who participated in two to five VR sessions, reported that sensations from their real limb were transferred to the muscles and joints of their phantom limb. In each case, phantom pain decreased during at least one of the sessions, suggesting that such therapy might offer pain relief for these types of patients.

The possibility of such a treatment seemed remote that afternoon in São Paulo, some 25 years ago, when I saw the boy shrieking in pain from a leg he no longer had. If I had known then what I know now, I would have been able to reassure the boy that what he was feeling, however excruciating and strange, was merely a phantasmagoric tactile memory of the past, created in every exquisite and cruel detail by a normally functioning brain—and not by a terrible curse. Perhaps by knowing that, my first patient would have found more bearable such a frightening and undesirable life companion. M

(Further Reading)

- **The Perception of Phantom Limbs: The D. O. Hebb Lecture.** V. S. Ramachandran and William Hirstein in *Brain,* Vol. 121, Part 9, pages 1603–1630; 1998.
- **Analgesia through the Looking Glass? A Randomized Controlled Trial Investigating the Effect of Viewing a "Virtual" Limb upon Phantom Limb Pain, Sensation and Movement.** Eric E. Brodie, Anne Whyte and Catherine A. Niven in *European Journal of Pain,* Vol. 11, No. 4, pages 428–436; published online July 20, 2006.
- **Phantom Limbs.** Ronald Melzack in *Scientific American Reports,* Vol. 16, No. 3, pages 53–59; September 2006.
- For information about amputation, see **www.answers.com/topic/amputation-3?cat=health**

Amputee Envy

People with body integrity identity disorder feel alienated from a part of their body and want to have it amputated. Researchers are unraveling clues to the causes of this bizarre condition *By Sabine Mueller*

In 1997 Robert Smith, a surgeon at the Falkirk and District Royal Infirmary in Scotland, fulfilled one of his patient's deepest desires: he amputated the lower part of the man's left leg. Smith performed a similar operation on a German retiree two years later, the British daily *The Independent* reported in 2000. Neither procedure was medically necessary. Both patients had told Smith that one of their legs was superfluous and that its mere presence had caused them enduring emotional pain.

Psychiatrists estimate that several thousand people worldwide, most of them male, wish to get rid of a normal healthy limb; a smaller number actually request its surgical removal. Such radical requests stem from an extremely rare psychiatric illness called body integrity identity disorder (BIID).

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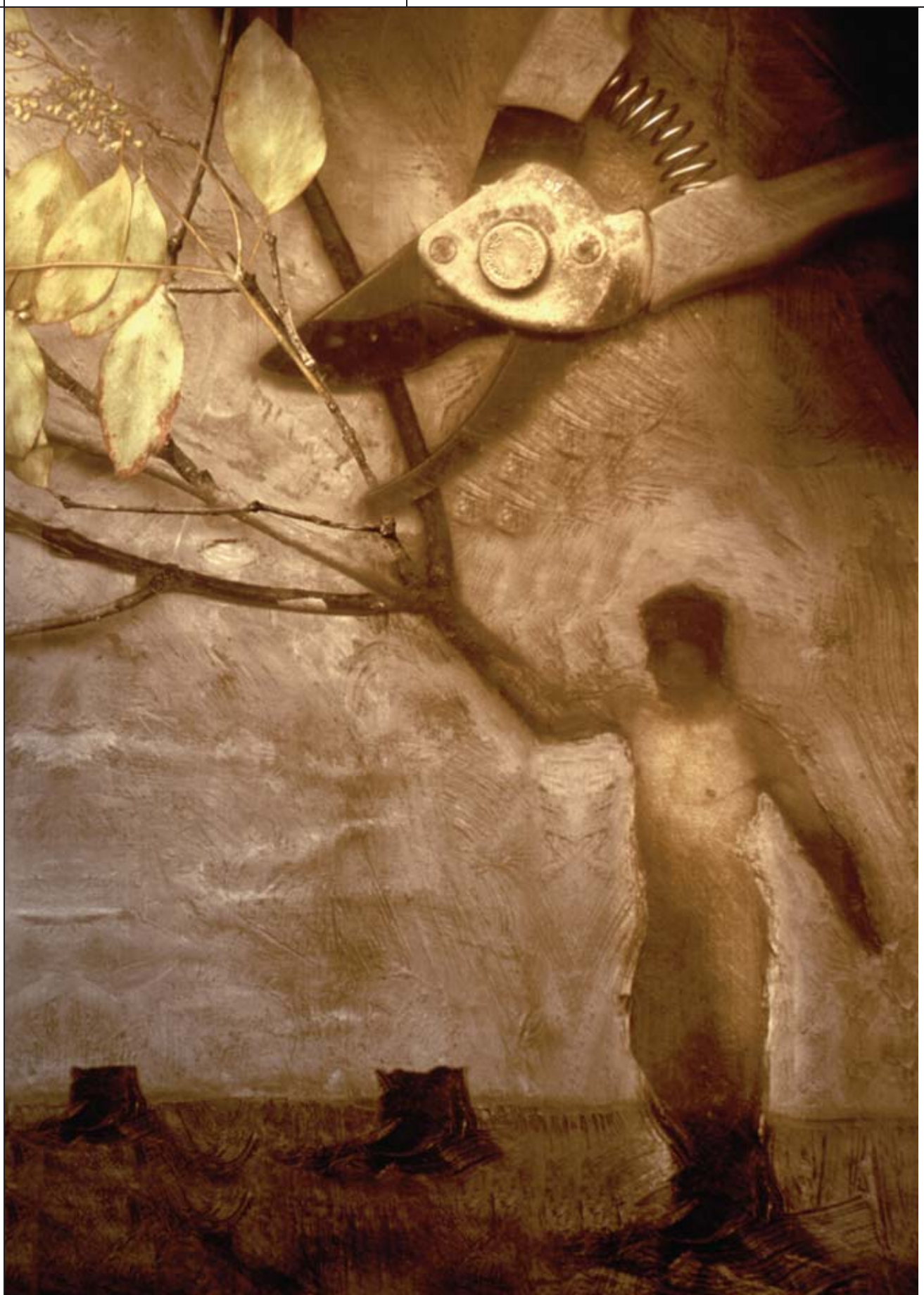


People who want an amputation often say that they are trying to establish their "true identity."

Other names for the condition include amputee identity disorder and apotemnophilia, meaning "amputation love." People with BIID report that a particular limb simply does not belong to them and that they suffer because they feel "overcomplete."

For such individuals, the wish to cut off a limb is not an idle fantasy but an obsessive need to extricate an alien appendage from their body. Many are distressed by such thoughts, which can disrupt their social life and distract them at work. The disorder can even be disfiguring or deadly: those who cannot afford or find willing surgeons may mutilate themselves by, for example, crushing a leg under weights, sawing off a finger or toe, placing the offensive limb in the way of an oncoming train, or packing the body part in dry ice in an attempt to freeze it to death.

As bizarre as such attempts may seem, recent research suggests that people with BIID are not delusional. Although early work hinted that BIID was induced by a sexual fetish with amputation, researchers have now largely turned to other explanations. One theory is that BIID patients long for disability as a way to gain attention that they lacked in childhood. Other research findings indicate, however, that the ailment arises from a neurological conflict between a person's anatomy and his or her body image. Such a conflict could stem, for example, from damage to a part of the brain that constructs the body image in maplike form.

No medication or psychotherapy technique has yet worked to dampen the pathological yearnings of people with BIID. Surgery, on the other hand, has apparently helped in some cases. Rather than resorting to such drastic measures, however, most doctors are hoping that scientific advances will lead to ways of correcting the underlying psychiatric problem, quenching the thirst for amputation before it leads to disability.

Defining the Desire

Since the late 1800s physicians and researchers have written about men and women who pretend to be or would like to become disabled. In 1977 the late sex researcher John Money and his colleagues at Johns Hopkins University described two individuals who wanted to become amputees because they found the idea sexually arousing. Money defined their problem as apotemnophilia, a sexual deviation, or paraphilia, in which a stump, pair of crutches or wheelchair is eroticized. He concluded that people seek amputation to attain sexual fulfillment.

Amorous yearnings do seem to play a role in many cases of BIID. In 1997 Richard L. Bruno, a specialist in brain-body disorders at the Englewood Hospital and Medical Center in New Jersey, described a subset of BIID patients who are sexually attracted to amputees and are thrilled by the idea of being an amputee; he dubbed such people "devotees." And psychiatrist Michael B. First of Columbia University reported in a 2004 paper that nearly 90 percent of 52 people with BIID felt sexually drawn to amputees.

But sexual urges do not fully explain the disorder. In First's study, only 15 percent of the subjects he interviewed said that sexual excitement was the primary reason for wanting to be an amputee. Similarly, Bruno identified a number of people whose desire for an amputation was not primarily driven by erotic fantasies but rather by disability itself. People he called "wannabes" yearn to become disabled, whereas another group, the "pretenders," seeks to simulate physical disability by, say, wrapping bandages around a limb and using a wheelchair or crutches.

Such people, Bruno argues, are looking for

FAST FACTS

Alien Limbs

1» Estimates suggest that several thousand people worldwide wish to get rid of a normal healthy limb. Such desires stem from an extremely rare psychiatric illness called body integrity identity disorder (BIID).

2» BIID can be distressing, disfiguring and deadly. The afflicted agonize over their dangerous desire and may even take matters into their own hands, by crushing a leg under weights or placing the offensive limb in the way of an oncoming train.

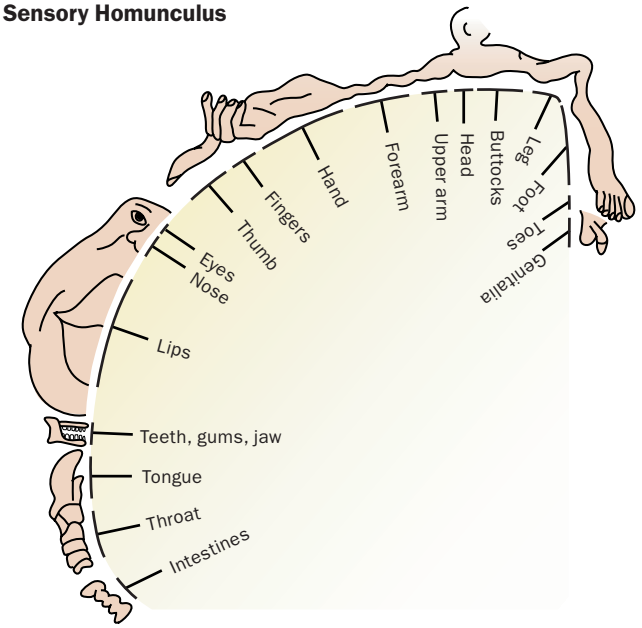
3» Some researchers believe that BIID arises from a conflict between a person's anatomy and his or her body image. Such a mismatch could result from damage in a part of the brain that contains a map of the body—a disparity that scientists hope to resolve.

Brain Maps of the Body

Neural pathways conduct information to and from sensory and motor neurons in the body and the cerebral cortex, the outermost layer of the brain. Signals conveying sensations such as touch and pain arrive in the foremost part of the parietal lobe at the somatosensory cortex, or the sensory homunculus, a Latin term meaning "little man." Here the signals coalesce to form a person's body image: nerve cells represent sensory receptors for different parts of the body in an organized map. The volume of brain matter dedicated to each body part reflects the density of sensory receptors in that area rather than the size of the body part. Therefore, parts of the little man's hands and face—especially the lips—are disproportionately large because their corresponding body regions are more densely populated with sensory nerve endings than, say, the buttocks or legs are.

The brain's motor center at the rear of the frontal lobe connects with muscles in the body and controls movement. A body map exists here, too, and like the sensory homunculus, this one represents the body parts most densely packed with muscles, such as the hands and face, as larger than areas with fewer muscles. In both brain maps, the right hemisphere contains a map of the left side of the body and the left hemisphere represents the right side. —*S.M.*

Sensory Homunculus



GEHIRN & GEIST/SIGANIM; SOURCE: PENFIELD AND RASMUSSEN, 1950

recognition and sympathy more than sexual gratification. He theorized that many of the afflicted lacked attention and love in childhood—when the disorder typically originates—and are looking to get these emotional supports through disability and dependency on others. In support of this theory, Bruno found that some pretenders came from households they described as cold, rigid and asexual. Many reported that as children they felt jealous of the attention received by people in wheelchairs and fantasizing, sometimes obsessively, about being cared for while disabled.

But other researchers characterize the disorder less as a desire for disability than as an anatomical identity crisis. In First's survey, almost two thirds of the subjects said they wanted an amputation primarily to establish their "true identity." For instance, one subject said, "I felt like I was in the wrong body—that I am only complete with both my arm and leg off on the right side."

First likens BIID to gender identity disorder, in which patients are similarly uncomfortable with part of their anatomy because it is at odds with their internal sense of self. Both BIID and gender identity disorder typically originate early in life and are sometimes successfully resolved with surgery. Such similarities suggest, according to First, that BIID is an identity disorder and should be classified as such in the *Diagnostic and Statistical Manual of Mental Disorders* (*DSM*), the standard handbook for mental health professionals.

Perturbed Body Maps

Such an identity crisis most likely has a neurological basis. Some researchers theorize that the

(The Author)

SABINE MUELLER is a physicist and philosopher. She coordinates the bioethics program at the Institute for Medical History, Theory and Ethics at the University Clinic Aachen in Germany.

Should Surgery Be an Option?

Ethicists disagree on whether surgeons should grant the wishes of patients with body integrity identity disorder (BIID) under any circumstances. The following statements represent opinions on both sides of the issue.

YES

If the desire for amputation is long-standing, the patient is not psychotic, and he is well aware of the risks and consequences, surgery is ethically permissible because it will prevent many BIID patients from injuring or killing themselves.

—Medical ethicists Tim Bayne of the University of Oxford and Neil Levy of the University of Melbourne in Australia

NO

Amputation of healthy limbs is a violation of the Hippocratic Oath, which instructs doctors to do no harm. From a psychiatric perspective, the desire of a BIID patient to amputate a limb is just as delusional as the desire of an anorexic to continue losing weight. In such cases, the person must be protected by the doctor from his or her own irrational desires.

In addition, the satisfaction often voiced after the procedure is not necessarily permanent—although the amputation is. Finally, significant costs to society could result if, for example, the person claims the right to medical rehabilitation and early retirement.

—Arthur Caplan, director of the Center for Bioethics at the University of Pennsylvania

disorder results from a distortion or deletion in one of the maplike representations of the body in the cerebral cortex, the brain's outermost layer [*see box on preceding page*]. For instance, brain damage might injure the neurons that create a piece of this body image, leading to a sense that a part of the body does not belong. Thus, a person might want to get rid of that part so that the body conforms to its representation in the brain.

Because brain damage would likely affect one particular spot in the map, such an injury or aberration could account for the fact that BIID patients typically want to rid themselves of a specific limb in a precise location. One of First's subjects, for example, wanted to cut off both legs above the knees, and that well-defined desire persisted even after he had his left arm amputated above the elbow after a shotgun accident. In fact, most of those in First's study who yearned for a leg amputation specified that they wanted it to occur above the knee.

What is more, body-image distortions are known to result from tumors or strokes in the parietal lobe, which contains a body map that is derived from sensory inputs. In a case described by British neurologist Oliver Sacks in his 1984 book *A Leg to Stand On* (Summit Books), a young man woke up to discover that someone else's leg was in bed with him; the man assumed it was from a corpse. But when he tried to throw it out of the bed, he landed on the floor himself. The leg was attached to him, but it seemed to be a counterfeit of his own, which had somehow vanished.

Physicians discovered a tumor above the patient's right parietal lobe that had begun to bleed during the night. Sacks posited that the tumor was corrupting his brain's body map. Once the tumor was removed, the man regained a normal impression of his physique.

Likening BIID to such cases of somatoparaphrenia, in which patients deny that a part of their body is theirs, neuroscientists Vilayanur S. Ramachandran and Paul McGeoch of the University of California, San Diego, suggested in a 2007 paper that parts of the parietal lobe might also be damaged in BIID patients. Such an insult could presumably decouple a specific part of the body from the body map in that lobe.

In other instances, BIID might result from a peripheral injury. In 1974 Sacks severely injured his left thigh in an encounter with a bull in the mountains of Norway. After the wound healed, he felt no connection to his thigh and occasion-

Corruption of the brain's body map might underlie some people's desire to get rid of a limb.

ally wished to have the leg amputated. Amputation, he wrote in *A Leg to Stand On*, would "relieve me of having to drag around a totally useless, functionless, and indeed 'defunct' limb." Sacks theorized that such bodily harm might in some circumstances interrupt communication between the limb and the brain.

Some BIID patients similarly recall childhood injuries involving the limb that they shortly thereafter became obsessed with amputating. In about one fifth of the subjects in First's 2004 study, a disability such as a limp or broken leg provided the impetus for their desire for an amputation. But many cases of BIID could stem from congenital aberrations in neural pathways, with injuries or other environmental factors playing a secondary role.

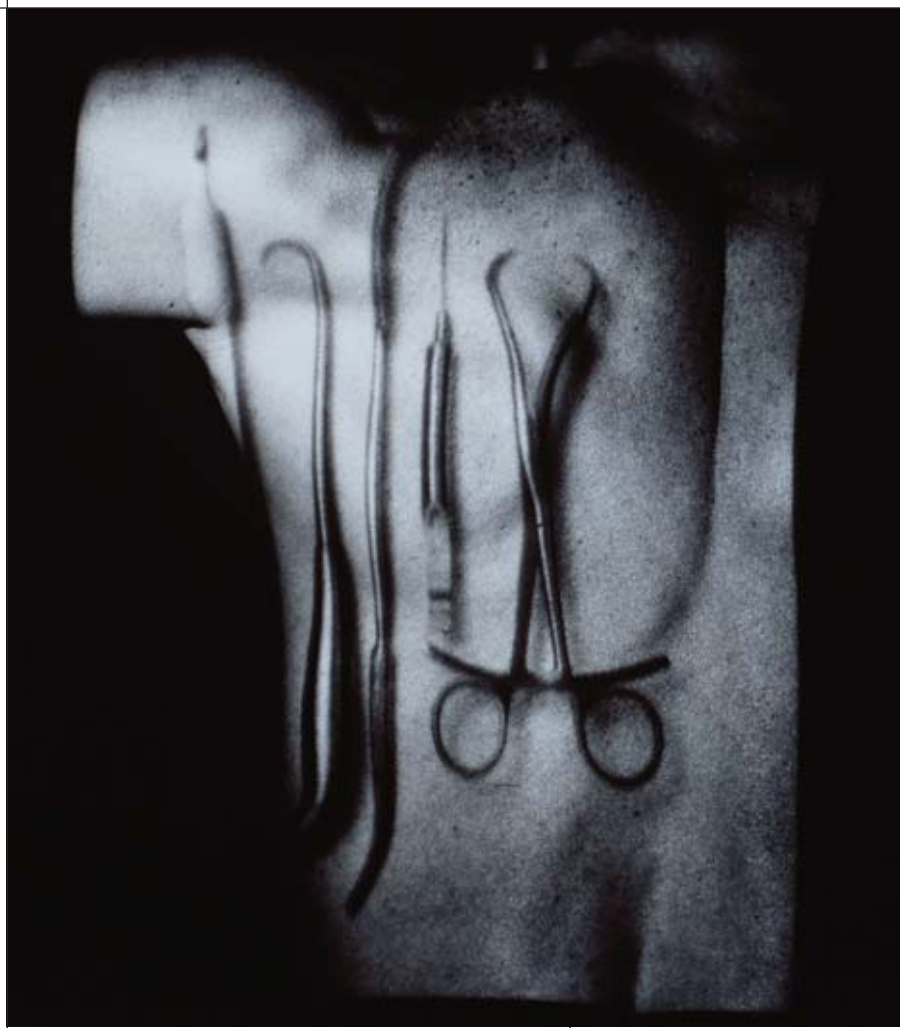
Curbing the Hunger

Traditional psychotherapy and medication, such as antidepressants, have so far had little effect on the desire for amputation. For instance, neither technique had much influence on BIID symptoms in the subjects in First's study who had tried it. In hopes of finding a more effective treatment, researchers are investigating ways to target the neurological underpinnings of BIID.

Sacks helped many of his patients with movement therapy, in which a therapist guides a patient through coordinated sequences requiring the use of the affected body part. Such therapy is thought to reintegrate the estranged body part with its representation in the brain. Sacks believes that a violin concerto by Mendelssohn helped to reincorporate his own leg into his body's neuromuscular walking program after his accident. "The leg came back" to the rhythm and melody of the music, the neurologist wrote.

Such simple cures may work to reinvigorate atrophied neural connections between body and brain. They may not be effective, however, if the foreign part of the body has actually been deleted from the brain's body map. A method under investigation by Ramachandran and McGeoch might work better in such instances. Rinsing an ear canal with warm and then cold water, which stimulates the half of the brain opposite the treated ear, temporarily alleviated somatoparaphrenia in stroke patients. The technique may work by exciting the parietal lobe, and the researchers now want to test it on people with BIID. If the method helps such patients, doctors might try the more lasting tactic of implanting electrodes that zap the relevant brain region directly.

Currently the most effective treatment for BIID may be the most damaging: surgery. The six patients in First's survey who had received an amputation at their desired location reported that the procedure abolished their yearning to cut off a limb and brought them great happiness. "Since I had it done five years ago," one person said of an amputation, "I've felt the best I've ever felt." Another remarked, "It finally put me at peace. I no longer have that constant, gnawing frustration." M



ROBERT DISCALFANI *Getty Images*

Crippling cravings: Many patients with body integrity identity disorder are so obsessed with having a limb amputated that they will do the deed themselves.

(Further Reading)

- **Devotees, Pretenders and Wannabes: Two Cases of Factitious Disability Disorder.** Richard L. Bruno in *Journal of Sexuality and Disability,* Vol. 15, No. 4, pages 243–260; 1997.
- **Amputee Identity Disorder: Information, Questions, Answers, and Recommendations about Self-Demand Amputation.** Gregg M. Furth and Robert Smith. 1st Books, 2000.
- **Out on a Limb.** Randy Dotinga in *Salon;* August 29, 2000.
- **Desire for Amputation of a Limb: Paraphilia, Psychosis, or a New Type of Identity Disorder.** Michael B. First in *Psychological Medicine,* Vol. 35, No. 6, pages 919–928; 2005.
- **At War with Their Bodies, They Seek to Sever Limbs.** Robin Marantz Henig in *New York Times;* March 22, 2005.
- General information about body integrity identity disorder is available at **www.biid.org**

PHILIP WHEELER www.agoodson.com

PSYCHEDELIC HEALING?

Hallucinogenic drugs, which blew minds in the 1960s, soon may be used to treat mental ailments

By David Jay Brown

Mind-altering psychedelics are back—but this time they are being explored in labs for their therapeutic applications rather than being used illegally. Studies are looking at these hallucinogens to treat a number of otherwise intractable psychiatric disorders, including chronic depression, post-traumatic stress disorder, and drug or alcohol dependency.

The past 15 years have seen a quiet resurgence of psychedelic drug research as scientists have come to recognize the long-underappreciated potential of these drugs. In the past few years, a growing number of studies using human volunteers have begun to explore the possible therapeutic benefits of drugs such as LSD, psilocybin, DMT, MDMA, ibogaine and ketamine.

Much remains unclear about the precise neural mechanisms governing how these drugs produce their mind-bending results, but they often produce somewhat similar psychoactive effects that make them potential therapeutic tools. Though still in their preliminary stages, studies in humans suggest that the day when people can schedule a psychedelic session with their therapist to overcome a serious psychiatric problem may not be that far off.

The Trip Begins

Psychedelic drug research began in 1897, when German chemist Arthur Heffter first isolated mescaline, the primary psychoactive compound in the peyote cactus. In 1943 Swiss chemist Albert Hofmann discovered the hallucinogenic effects of LSD (lysergic acid diethylamide) at Sandoz Pharmaceuticals in Basel while studying ergot, a fungus that grows on rye. Fifteen years later, in 1958, he was the first to isolate psilocybin and psilocin—the psychoactive components of the Mexican "magic mushroom," *Psilocybe mexicana*.

Before 1972, close to 700 studies with psychedelic drugs took place. The research suggested that psychedelics offered significant benefits: they helped recovering alcoholics abstain, soothed the anxieties of terminal cancer patients, and eased the symptoms of many difficult-to-treat psychiatric illnesses, such as obsessive-compulsive disorder.

For example, between 1967 and 1972 studies in terminal cancer patients by psychiatrist Stanislav Grof and his colleagues at Spring Grove State Hospital in Baltimore showed that LSD combined with psychotherapy could alleviate symptoms of depression, tension, anxiety, sleep disturbances, psychological withdrawal and even severe physical pain. Other investigators during this era found that LSD may have some interesting potential as a means to facilitate creative problem solving [*see box on page 70*].

Between 1972 and 1990 there were no human studies with psychedelic drugs. Their disappearance was the result of a political backlash that followed the promotion of these drugs by the 1960s counterculture. This reaction not only made these substances illegal for personal use but also made it extremely difficult for researchers to get government approval to study them.

Things began to change in 1990, when "open-minded regulators at the FDA decided to put science before politics when it came to psychedelic and medical marijuana research," says Rick Doblin, a public policy ex-

Psychedelic drugs affect **all mental functions:** perception, emotion, cognition, body awareness and one's sense of self.

pert and head of the Multidisciplinary Association for Psychedelic Studies (MAPS). "FDA openness to research is really the key factor. Also, senior researchers who were influenced by psychedelics in the sixties now are speaking up before they retire and have earned credibility." Chemist and neuropharmacologist David E. Nichols of Purdue University adds, "Baby boomers who experienced the psychedelic sixties are now mature scientists and clinicians who have retained their curiosity but only recently had the opportunity to reexplore these substances."

Research Begins Anew

The efforts of two privately funded organizations have catalyzed much of the recent wave of research: MAPS, founded in 1986 by Doblin, and the Heffter Research Institute, started in 1993. Outside the U.S. there are groups such as the Beckley Foundation in England and the Russian Psychedelic Society. These seek out interested researchers, assist in developing the experimental design for the studies, and help to obtain funding and government approval to conduct clinical trials. They have initiated numerous FDA-approved clinical trials in the U.S., Switzerland, Israel and Spain. So far the agency has approved seven studies, with two under review and more on the way.

Current studies are focusing on psychedelic treatments for cluster headaches, depression, obsessive-compulsive disorder (OCD), severe anxiety in terminal cancer patients, post-traumatic stress disorder (PTSD), alcoholism and opiate addiction. New drugs must pass three clinical milestones before they can be marketed to the public, called phase I (for safety, usually in 20 to 80 volunteers), phase II (for efficacy, in several hundred subjects) and phase III (more extensive data on safety and efficacy come from testing the drug in up to several thousand people). All the studies discussed in this article have received government approval, and their investigators are either in the process of recruiting human subjects or have begun or completed research on human subjects in the first or second stage of this trial process.

Psychedelic drugs affect all mental functions: perception, emotion, cognition, body awareness and one's sense of self. Unlike every other class of drugs, psychedelic drug effects depend heavily on the environment and on the expectations of the subject, which is why combining them with psychotherapy is so vital.

"Psychedelics may be therapeutic to the extent that they elicit processes that are known to be useful in a therapeutic context: transference reactions and working through them; enhanced symbolism and imagery; increased suggestibility; increased contact between emotions and ideations; controlled regression; et cetera," says psychiatrist Rick Strassman of the University of New Mexico School of Medicine, who from 1990 to 1995 performed the first human study using psychedelic drugs in about 20 years, investigating the effects of DMT on 60 human subjects. "This all depends, though, on set and setting," he cautions. "These same properties could also be turned to very negative experiences, if the support and expectation for a beneficial experience aren't there."

Mechanisms and Targets

Scientists divide classical psychedelic drugs into two basic chemical groups: tryptamines (such as LSD, DMT and psilocybin) and phenethylamines (such as mescaline and MDMA). In addition, some people consider so-called dissociative anesthetics (such as ketamine and PCP) to be psychedelic drugs, although the way they affect the brain is quite different.

The exact mechanisms differ, but all the tryptamine hallucinogens—which make up the

FAST FACTS

Mind-Bending Therapies

1» **The drugs that put the "psychedelic" into the sixties are now the subject of renewed research interest because of their therapeutic potential.**

2» **Psychedelics such as LSD and the compound in magic mushrooms could ease a variety of difficult-to-treat mental illnesses, such as chronic depression, post-traumatic stress disorder, and drug or alcohol dependency.**

3» **Clinical trials with various substances are now under way in humans.**

majority of psychedelic drugs—selectively bind to specific serotonin receptors on neurons, mimicking the effects of the nerve-signaling chemical, or neurotransmitter, serotonin on these receptors. Phenethylamines mimic the chemical structure of another neurotransmitter, dopamine. They actually bind to many of the same serotonin receptors activated by the tryptamines, however. Serotonin is responsible for many important functions, including mood, memory, appetite, sex and sleep. It is such an essential neurochemical that any substance—such as a hallucinogen—that interferes with its action might be expected to produce dramatic changes in brain function.

How do the drugs create their perceptual effects? Neuroscientists believe that activation of a particular set of serotonin receptors, the 2A subtype, which are highly expressed (or present) in the cortex, the outermost layer of the brain, interferes with the processing of sensory information. Consciousness is thought to involve a complex interaction among the cortex, the thalamus and the striatum. Disruption of this network by activation of serotonin 2A receptors is now the most popular theory for the mechanism of action for tryptamine and phenethylamine psychedelics.

"There are at least two possible mechanisms for beneficial actions," Nichols says. "The first simply involves a change in the numbers of brain serotonin 2A receptors. Activation of serotonin 2A receptors by psychedelics causes the number of receptors expressed on the surface of neurons to decrease, a process called downregulation. For some disorders, such as OCD, it may be this receptor downregulation that could be therapeutic," he explains. "The other possible mechanism is a psychological effect that is harder to define but in some way produces changes in the way the subject perceives pain and distress. Psychedelics seem able to produce a profound cognitive change that provides the patient with a new insight—the ability to see the world from a new perspective—somehow reducing anxiety and raising the pain threshold."

MDMA (3,4-methylenedioxy-*N*-methylamphetamine) is also chemically classified as a phenethylamine, but its action in the brain is substantially different from that of other drugs discussed in this article. "In contrast to most psychedelics, MDMA does not directly stimulate serotonin 2A receptors but instead causes dopamine, serotonin and norepinephrine [another neurotransmitter] to be released from their stores in neuron endings," Nichols says. There is some controversy about whether MDMA has neurotoxic effects. Most researchers believe, however, that the occasional moderate use of MDMA at therapeutic doses would not be damaging. There have been no recent studies using mescaline, although MAPS plans to initiate some in the future.

In contrast to the traditional psychedelics, the dissociative anesthetics selectively bind to *N*-methyl-D-aspartic acid (NMDA) receptors, blocking the neurotransmitter glutamate from activating these receptors. "Because glutamate is an essential neurotransmitter that activates neurons, this blocking effect seems to prevent the processing of sensory information by the brain," Nichols states.

Ketamine appears to hold particular promise as a psychedelic therapy because it is already among the selections in Western medicine's pharmacopoeia. In addition to being part of a different chemical class of drugs than the other psychedelics, ketamine is in a separate legal class as an FDA-approved schedule III drug. This designation means that any physician can administer it for an off-label use if he or she believes it will help the patient.

Although some research indicates that psy-

Psychedelic parade: the ergot fungus, which contains a precursor to LSD (*left*); tablets of LSD (*center*); and "magic mushrooms" (*right*).

NIGEL CATTLIN *Photo Researchers, Inc. (left)*; TEK IMAGE *SPL/Photo Researchers, Inc. (center)*; MARTIN BOND *SPL/Photo Researchers, Inc. (right)*

(The Author)

DAVID JAY BROWN holds a master's degree in psychobiology from New York University and has been interviewing accomplished thinkers about their creative process for more than 20 years. He is author of *Mavericks of Medicine* (Smart Publications, 2007) and six other books about the frontiers of science and medicine. The author wishes to thank chemist and neuropharmacologist David E. Nichols of Purdue University for his invaluable assistance in describing the neurochemistry of psychedelic drugs.

A Spark for Creativity?

Nobel Prize winners Francis Crick and Kary Mullis reportedly attributed part of their breakthrough scientific insights to psychedelic drugs. And architect Kyosho Izumi's LSD-inspired design of the ideal psychiatric hospital won a commendation for outstanding achievement from the American Psychiatric Association. Others scoff at the notion that the drugs deserve the credit. What do studies say?

In 1955 psychiatrist Louis Berlin investigated the effects of mescaline and LSD on the painting abilities of four nationally recognized artists. Although the study showed that the artists' technical abilities were hampered, a group of independent art critics judged the experimental paintings to have "greater aesthetic value" than the artists' usual work.

Two years later Los Angeles psychiatrist Oscar Janiger asked 60 prominent artists to paint a Native American doll before taking LSD and then again while under its influence. A panel of independent art critics and historians then evaluated the results. Members generally agreed that the craftsmanship of the second set of paintings suffered, but many of those pieces received higher marks for imagination.

Under the influence: An abstract painting produced two hours after an artist ingested LSD for an experiment (*left*) and a Kachina doll painted before the drug experience.

In 1965 psychologist James Fadiman and social scientist Willis Harman of San Francisco State College administered mescaline to workers in various fields as they sought a creative solution for a professional problem. After some psychological preparation, subjects worked individually on their problem throughout their mescaline session. Psychological tests, subjective reports, and the eventual industrial or commercial validation and acceptance of the finished product or final solution measured the output of each volunteer. Virtually all individuals produced solutions judged highly creative and satisfactory by these standards.

Psychologist Stanley Krippner of the Saybrook Graduate School and Research Center in San Francisco, however, remains skeptical. "It is naive to claim that psychedelics produce creative experience," he argues. "At best, they may be one of many factors that result in something new that comes into being." —*D.J.B.*

FROM *LSD, SPIRITUALITY AND THE CREATIVE PROCESS: BASED ON THE GROUNDBREAKING RESEARCH OF OSCAR JANIGER, M.D.*, BY MARLENE DOBKIN DE RIOS AND OSCAR JANIGER. INNER TRADITIONS/PARK STREET PRESS, 2003

chedelic drugs may enhance suggestibility and certain aspects of psychotherapy, the benefits of dissociative anesthetics such as ketamine and ibogaine may simply be the result of enduring biochemical changes in the brain. For example, in 2006 Carlos Zarate of the National Institute of Mental Health published a study demonstrating ketamine's unusual antidepressant properties [see "Good News about Depression," by Walter Brown; Scientific American Mind, June/July 2007]. A single infusion of ketamine relieved symptoms of depression in some patients within a few hours, and that relief persisted for several days.

This was the third study that showed ketamine's powerful and enduring antidepressant effects. In an intriguing finding from one of the previous studies, subjects received the ketamine as an anesthetic for orthopedic surgery—so they were not even conscious during the mind-altering segment of the drug's action in the brain—and the antidepressant effects occurred postoperatively.

In other work seeking to help cure addicts, a preliminary ketamine study, in which psychiatrist Evgeny Krupitsky of St. Petersburg, Russia, treated 59 patients with heroin dependency, produced encouraging results. And the Iboga Therapy House in Vancouver, Canada, has recently begun a study that has so far successfully treated three out of 20 opiate-addicted subjects with ibogaine. The experimental procedure substantially reduced the withdrawal symptoms associated with opiate addiction, helping the addicts to recover and break their dependency on the drug.

OCD, Cluster Headaches and Cancer

In addition to the promising work with ibogaine and the dissociative anesthetics, progress is also being made in the study of conventional psychedelics. In 2006 investigators at the Johns Hopkins School of Medicine published the results of a six-year project on the effects of psilocybin, in which more than 60 percent of the par-

"We saw a **drastic decrease** in symptoms. People reported that it had been years since they had felt so good."

ticipants reported positive changes in their attitude and behavior after taking the drug, a benefit that lasted for at least several months.

In another 2006 study, researchers at the University of Arizona, led by psychiatrist Francisco Moreno, found that psilocybin relieved the symptoms of nine patients with OCD. The patients suffered from a wide range of obsessions and compulsions. Some of them showered for hours; others put on their clothes over and over again until they felt right. All nine experienced improvements with at least some of the doses tested.

"What we saw was a drastic decrease in symptoms for a period of time," Moreno says. "People would report that it had been years since they had felt so good." Moreno cautions that the goal was simply to test the safety of administering psilocybin to OCD patients and that the true effectiveness of the drug is still in question until a larger controlled study can be conducted. Such a study is being planned, although there are currently no funds available for it. According to Moreno, however, no treatment in the medical literature eases OCD symptoms as fast as psilocybin does. Whereas other drugs take several weeks to show an effect, psilocybin worked almost immediately.

Preliminary results of a current study led by psychiatrist Charles Grob of the Harbor-UCLA Medical Center suggest that psilocybin may reduce the psychological distress associated with terminal cancer. This research seeks to measure the effectiveness of psilocybin on the reduction of anxiety, depression and physical pain in advanced-stage cancer patients. Grob's study is almost complete; 11 out of 12 subjects have already been treated. Although the formal data analysis has not been completed, "my impression," Grob says, "from just staying in touch with these people and following them is that some do seem to be functioning better psychologically. There seems to be less anxiety, improved mood and an overall improved quality of life. There also seems to be less fear of death."

The first studies of psychedelic drugs at Harvard University since 1965 are also now under way. In one study, psychiatrist John Halpern and his colleagues are looking into using LSD and psilocybin to treat the debilitating symptoms of cluster headaches. The researchers, who are in the process of recruiting subjects, will probably begin trials in early 2008.

Acute Anxiety and PTSD

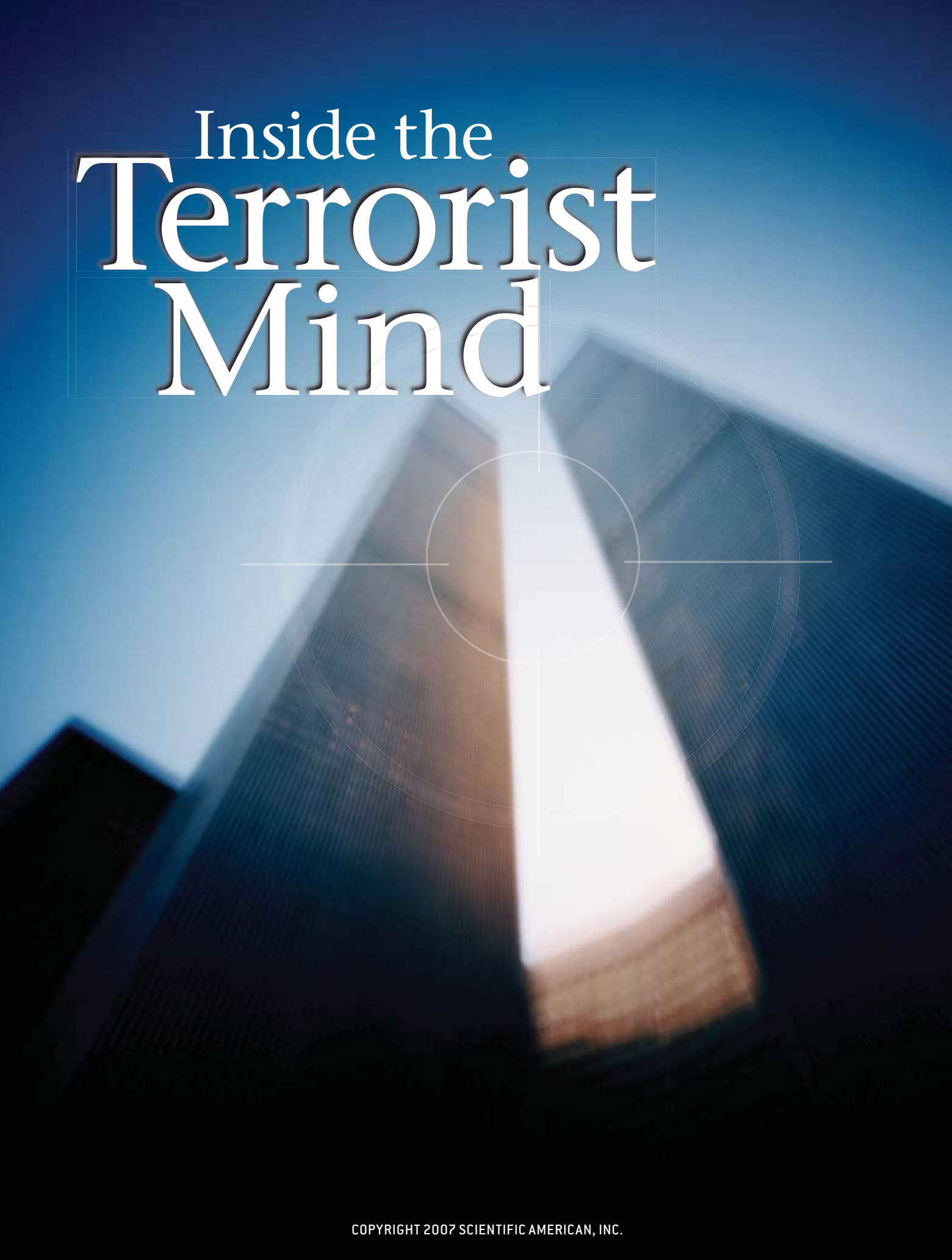
Another study at Harvard, also led by Halpern, will look into MDMA-assisted psychotherapy in subjects with anxiety associated with advanced-stage cancer—similar to Grob's psilocybin study—using measures to evaluate anxiety, pain and overall quality of life. This study is also in the process of recruiting human subjects.

Psychiatrist Michael Mithoefer in Charleston, S.C., is running an MDMA study for treatment-resistant PTSD victims of crime, war or childhood sexual abuse. So far 17 out of 20 such subjects have already undergone the experimental therapy. "At this point the results are very promising," Mithoefer says. "I think we're seeing pretty strong, robust effects in some people. I hasten to add these are preliminary findings—we're not ready to draw conclusions yet. But assuming it keeps going this way for the rest of the study, it certainly seems that there's very good reason to go on to larger phase III trials."

Although we are still in the early days of psychedelic therapy research, the initial data show considerable promise. A growing number of scientists believe that psychedelic drugs may offer safe and effective help for people with certain treatment-resistant psychiatric disorders and could possibly help some people who receive partial relief from current methods to obtain a more complete healing. M

(Further Reading)

- **Hallucinogens.** D. E. Nichols in *Pharmacology & Therapeutics,* Vol. 101, No. 2, pages 131–181; February 2004.
- **Safety, Tolerability, and Efficacy of Psilocybin in 9 Patients with Obsessive-Compulsive Disorder.** F. A. Moreno, C. B. Wiegand, E. K. Taitano and P. L. Delgado in *Journal of Clinical Psychiatry,* Vol. 67, No. 11, pages 1735–1740; November 2006.
- **The Use of Psilocybin in Patients with Advanced Cancer and Existential Anxiety.** C. S. Grob in *Psychedelic Medicine: New Evidence for Hallucinogenic Substances as Treatments,* Vol. 1. Edited by Michael J. Winkelman and Thomas B. Roberts. Praeger/Greenwood Publishing Group, 2007.
- **MDMA-Assisted Psychotherapy for the Treatment of Posttraumatic Stress Disorder.** M. Mithoefer. Ibid.
- The Multidisciplinary Association for Psychedelic Studies (MAPS) publishes a quarterly bulletin that reports on the status of current scientific research into psychedelic substances: **www.maps.org**



Inside the Terrorist Mind

Scientists are probing the psyches of terrorists to reveal what motivates their monstrous acts. Far from being crazed killers, terrorists are gunning for the greater good—as they see it

By Annette Schaefer

On June 30 two men drove a dark green Jeep Cherokee into a set of doors at the Glasgow airport in Scotland, producing a burst of flames that officials deemed an act of terrorism. They linked the crash to a broader plot that included two cars in London that contained explosive materials.

The foiled plan is just one of the tens of thousands of terrorist pursuits that have pockmarked the globe in recent decades—including the 1972 murder of 11 Israeli athletes at the Munich Olympics, the 1975 hostage taking at the OPEC headquarters in Vienna, the 1995 sarin gas attacks in Tokyo, and the September 11, 2001, strikes in the U.S. Although terrorism includes a diversity of actions, all of them, by definition, are intended to harm innocent civilians—and perpetrate fear—in the name of political, religious or other ideological goals.

Terrorism is an ageless scourge. But the ferocity of the 9/11 assaults and the upsurge in unrestrained activities by al-Qaeda and other groups have elicited heightened interest in unraveling the underpinnings of terrorism. Accompanying this brand of audacious intimidation is a new tactic for studying it—and perhaps curtailing it. Whereas earlier generations of researchers focused on the political roots of groups such as the Irish Republican Army (IRA), many of today's investigators are probing the minds of adherents to discover what drives them to carry out their demonic deeds.

Literature on this approach abounds. Amazon.com offers more than 800 books on "psychology and terrorism." According to the psychology database PsycInfo, more articles on terrorism have been published since 2001 than in the previous 120 years. Meanwhile the U.S. Department of Homeland Security has doled out

CHRISTIAN HOEHN Getty Images

Police forensic officers survey the wreckage after a Jeep crashed through an entrance at Glasgow airport in Scotland on June 30, 2007. Officials called the incident an act of terrorism.

$12 million to establish the Study of Terrorism and Responses to Terrorism (START), a research consortium of more than 30 scientists charged with investigating the origins, dynamics and psychological impacts of this devastating pursuit.

The latest research suggests, for example, that the vast majority of terrorists are not mentally ill but are essentially rational people who weigh the costs and benefits of terrorist acts, concluding that terrorism is profitable. The advantages accrued, however, have value only in a particular social context. Group dynamics, often driven by charismatic leadership, play a powerful role in convincing individuals to embrace expansive goals and use violence to attain them. Personal factors also draw people toward terror. Terrorist groups provide their members with a feeling of belonging and empowerment and, in some cases, a means of avenging past wrongs.

To be sure, many of the psychological explanations of terrorism rest on shaky ground, because empirical studies of the terrorist mind are relatively scarce, partly because of the difficulty in conducting them [*see box on page 77*]. "The number of suggested theories far outstrips the number of empirical studies in the literature," says psychiatry professor Jeff Victoroff of the University of Southern California. Nevertheless, researchers hope that the insights gained will help them thwart terrorism by dissolving the psychological glue that holds these rebel groups together.

FAST FACTS

Dissecting Terror

1» **Whereas earlier researchers focused on the political roots of terrorism, many of today's investigators are probing the psychological factors that drive adherents to commit their deadly deeds.**

2» **Most terrorists are not mentally ill; rather they rationally weigh the costs and benefits of their actions and conclude that terrorism is profitable.**

3» **Group dynamics and charismatic leadership play powerful roles in convincing people to embrace the expansive goals of terrorism. Terrorist groups often provide their members with a sense of belonging and empowerment.**

Rise of Religion

Modern-day terrorism can be traced back as far as the first century A.D., when the Zealots of Judea secretly assassinated Roman occupation forces and collaborators because they felt that Roman rule was incompatible with Judaism. Like other religious extremists, the Zealots rejected the authority of a secular government and laws that did not incorporate their beliefs.

Centuries later the rise of nationalism engendered a new breed of terrorist, exemplified by the IRA, loyal to a collection of people who share the same culture and values. Most such nationalists aim to create or reclaim a homeland; their actions are designed to garner international sympathy for their cause and to coerce the dominant group to concede to their wishes. Social revolutionary terrorists such as the German Red Army Faction (RAF) and the Italian Red Brigades, on the other hand, seek to overthrow capitalism and the current social order.

During the 1970s and 1980s nationalists and social revolutionaries were responsible for most acts of terrorism. Both groups sought to influence the West and the establishment and consistently owned up to their deeds. But in recent decades no

CHRIS JAMES *Bloomberg News/Landov*

one has claimed responsibility for perhaps 40 percent of terrorist incidents, a fact experts attribute to the increasing frequency of terrorism perpetrated by religious extremists—modern terrorists in the tradition of the Zealots of Judea.

Unlike the more politically motivated factions, these religious terrorists do not seek influence per se but rather the destruction of the Western world in the name of God. (As such, attribution is superfluous. After all, God knows what happened.) This motive reveals why they are so dangerous: they are unconstrained by the negative Western political reaction, and instead of fearing death they embrace martyrdom. Thus, they are willing to spawn casualties with abandon, as demonstrated on September 11 and by the bombings of the U.S. embassies in Kenya and Tanzania in 1998 and the U.S.S. *Cole* in 2000.

The February 1998 fatwa issued by the World Islamic Front illustrates this destructive mind-set. It reads in part: "In compliance with God's order, we issue the following fatwa to all Muslims: The ruling to kill the Americans and their allies—civilians and military—is an individual duty for every Muslim who can do it … to liberate the al-Aqsa Mosque and the holy mosque (Mecca) from their grip, and in order for their armies to move out of all the lands of Islam, defeated and unable to threaten any Muslim."

Cool Operators

Such a mind-set may seem almost pathological. Indeed, many people reflexively brand terrorists as "crazy"; some researchers, too, have suspected psychiatric problems such as antisocial personality disorder as a cause of political or religious violence. Studies of members of the RAF in Germany, the IRA in Ireland and Hezbollah in Lebanon, among others, however, have yielded no evidence that terrorists are mentally ill.

Even suicide bombers are sane in most respects. After interviewing some 250 members of Hamas and Islamic Jihad in Gaza from 1996 to 1999, United Nations worker and journalist Nasra Hassan reported that none of these young would-be bombers struck her as depressive or despondent. They always discussed the attacks matter-of-factly and were motivated by deep religious feelings and the conviction that what they were doing was right.

An expert committee on the psychological causes of terrorism concluded in 2005 that individual psychopathology was insufficient to explain terrorism. In fact, terrorist leaders typically screen out such people from their organizations because their instability makes them dangerous. Instead many researchers now believe that, far from being lunatics, terrorists rationally calculate the costs and benefits of their actions. In this "rational choice" theory of terrorism, violence and the perpetration of fear make up an optimal strategy for achieving political and religious objectives.

Autobiographical tracts from terrorists such as Sean MacStiofain, the first chief of staff of the Provisional IRA, Palestine Liberation Organization activist Leila Khaled and the Brazilian guerrilla fighter Carlos Marighella support this view, according to terrorism expert Martha Crenshaw

Terrorist Types

Terrorists can have a variety of motivations. In addition to the classifications of nationalists, social revolutionaries and religious fanatics, officials have identified at least four other terrorist brands. These include:

Terrorist Timothy McVeigh blew up the Alfred P. Murrah Federal Building in Oklahoma City on April 19, 1995.

- **Special-interest groups.** These people hang on the radical fringe of legitimate causes. They use terrorism to defend their views, say, against abortion or in support of animal rights.
- **Right-wing societies.** These groups seek to preserve the dominance of a threatened ethnic majority, often espousing racist, anti-Semitic and antigovernment views. Oklahoma City bomber Timothy McVeigh was such an activist.
- **Nontraditional religious extremists.** Cults such as Aum Shinrikyo (now known as Aleph), which perpetrated the 1995 sarin gas attacks in the Tokyo subways, aim to destroy a demonized enemy and precipitate an apocalypse.
- **Lone terrorists.** Shunned by groups, seriously disturbed individuals tend to act alone. For example, Theodore Kaczynski, aka the Unabomber, killed three people and injured another 23 with letter bombs—ostensibly to attract attention to what he believed were the dangers of modern technology.

JIM BOURG *Reuters/Landov*

"Being a terrorist is not usually a full-time job. Most terrorists go to work and see friends and family."

of Wesleyan University. These writings reveal that intellectualism can coexist with hatred and that political theorizing is a common outlet for frustration over political grievances. The theorizing becomes dangerous when it hardens into dogma.

Studies of the militant Islamist jihadists reveal similar signs of normalcy tucked inside fanaticism. After culling through government documents, media reports and court records on 400 of these extremists, forensic psychiatrist Marc Sageman of the University of Pennsylvania determined that these individuals are far from brainwashed, socially isolated, hopeless fighters. Ninety percent of them came from caring, intact families; 63 percent had gone to college, compared with the 5 to 6 percent background rate in the developing world, according to Sageman. Similarly, the suicide hijackers of 9/11 were well educated—three of them were in graduate school—and offspring of well-off Saudi and Egyptian families.

"These are the best and brightest of their societies in many ways," Sageman wrote in an essay about his 2004 book *Understanding Terror Networks*. "Terrorists are generally completely normal people.... People just like you and me."

Of course, not all terrorists come from financially and socially solid backgrounds. When Israeli social scientists conducted postmortem profiles of 93 Palestinian suicide bombers, aged 17 to 22, the scientists found that the bombers had been uniformly uneducated, unemployed and unmarried.

No matter their background, what seems to unite all terrorists is a willingness to subordinate their individual identity to a collective identity, according to political psychologist Jerrold M. Post of George Washington University. A growing number of researchers, including Post, believe terrorism can be best understood through the lens of group psychology. It is in that group context that terrorists' rational calculus makes sense, as the benefits of terrorism are generally those of the group and not of the individual.

> What unites terrorists is a willingness to subordinate an individual identity to a collective identity.

Rescue workers attend to victims of a suicide bombing at the old central bus station in Tel Aviv, Israel, on April 17, 2006.

RAANAN COHEN Reuters/Landov

You Belong to Us

Charismatic leaders play an important role in setting these goals and convincing followers to embrace them. According to an article by Post in *eJournal USA*, Palestinian suicide bomb commanders have told their recruits: "You have a worthless life ahead of you, you can do something significant with your life, you will be enrolled in the hall of martyrs...." The bombers themselves then embrace the larger aims of their mission at great personal cost. When Massachusetts Institute of Technology graduate student Nichole Argo interviewed 15 Palestinians in Israeli prisons who had gone on failed suicide missions in 2003, she, too, found that they placed the interests of their society above their own welfare.

Osama bin Laden similarly convinced the 9/11 attackers to adopt his cause and subordinate their personal welfare to it. Like a religious cleric, bin Laden regularly referred to verses of the Qur'an to validate acts of extreme violence.

In Middle Eastern cultures, extremist political goals frequently are inculcated into young people very early in life. From interviews with 35 incarcerated Middle Eastern terrorists, Post and his colleagues learned that adults routinely teach

Investigating Terror

On Anne Speckhard's last trip to Lebanon, Hezbollah offered her an interview with one of the leading members of the organization. The psychologist from the Free University of Brussels in Belgium had to decide whether to climb into a car and be transported to an undisclosed meeting place. "The most difficult thing is to calculate the danger in which one is putting oneself as a researcher," Speckhard says. Could she trust the mediators and activists?

United Nations worker and journalist Nasra Hassan was exposed to similar peril when she met with members of Hamas and Islamic Jihad in Gaza in the mid- to late 1990s. The encounters took place in cafés, on the beach or in darkened back rooms. Many of the interviewees hid their faces with masks, and all of them demanded strict anonymity. "I was warned that my interest in trying to understand the suicide missions was dangerous," Hassan wrote in the *New Yorker.*

"The conditions under which empirical terrorism research is conducted are the most difficult that one can imagine," says criminologist Lorenz Boellinger of the University of Bremen in Germany. Studying terrorists still at large, as Speckhard and Hassan have done, may be the tactic most fraught with risk. Contact with such people can be extremely dangerous and requires costly and arduous travel. In addition, researchers who seek to speak with terrorists frequently come to the attention of security forces and the military. They run the risk of being seen as sympathizers and of being interrogated.

The scientific benefits are sometimes dubious as well: terrorists may not discuss their motivations and feelings openly, for example, instead spewing useless propaganda. Even when terrorists are candid, their insights may never be published. In the late 1980s Ariel Merari of the University of Tel Aviv spoke to imprisoned Hezbollah and Amal fighters, among members of other pro-Syrian groups, and gave them standardized psychological tests. His data, however, have been classified by the Israeli security service and are thus no longer accessible.

Despite these drawbacks, many researchers consider personal contact with perpetrators essential. Information from trial records is always filtered, and statements from family and friends provide an extremely subjective, if superficially complete, picture. "In the final analysis, you have to take the risk to go where the terrorists are," Speckhard says, "even though your life may be on the line." —*A.S.*

children to hate the enemy, Israel, and to believe in the cause of defeating Israeli forces. One of the interviewees reported that he learned from the sheikh at his mosque how the enemy effectively evicted Palestinians from Palestine.

In interviews done by Post's team, militant Islamist terrorists from Hezbollah and Hamas justified suicide terrorism by terming it martyrdom, or self-sacrifice, in the name of Allah. Thus, such acts fulfilled another socially prescribed goal: they underscored the depth of a person's faith. Social context was critical to this idea. The researchers found that religiously motivated Islamist terrorists were more committed to self-sacrifice than were less religious perpetrators, whose objectives were purely political.

The Chechen rebels who held 800-odd Moscow theatergoers captive for 58 hours in October 2002 were equally committed to self-sacrifice for the supposed greater good. According to a 2004 study in which psychologist Anne Speckhard of the Free University of Brussels in Belgium interviewed 11 of the hostage survivors, the Chechen "freedom fighters" knew what they wanted: independence and an end to the harsh occupation of Chechnya.

At the same time, their religious beliefs motivated them to become martyrs for their cause. Nothing was more important to them than dying for their homeland. During the siege, one terrorist reportedly said, "All of us have the same fate here. We are here to die." Terrorism was thus used as a means to fight back and to find personal meaning and justice where they were perceived as lacking.

Signing Up for Terror

Indeed, joining a radical group provides a sense of community, power and identity to people who might otherwise feel alone, powerless

(The Author)

ANNETTE SCHAEFER is an economist and independent science journalist based in Chicago and Cologne, Germany.

Group Forces at Work

Psychologist John Horgan, who directs the International Center for the Study of Terrorism at Pennsylvania State University, believes that group processes turn political radicalism to violence.
Interview by Steve Ayan

Scientific American Mind: What turns an individual into a terrorist?
Horgan: Research over the past 40 years shows that there is no single cause and no set progression. One terrorist may act as a lone fighter; others land in a setting that engenders a radical mind-set; still others engage in terrorism to retaliate for perceived wrongs and slights. The idea that the development of a terrorist can always be traced to a single cause—whether to a particular personality type or particular experiences—is naive.

Mind: Is the image of a "paranoid killer" a fiction?
Horgan: There will always be sporadic instances of such personalities. But the demands of a life of terrorism pretty much preclude paranoid people. Terrorists are always under a high degree of pressure: they fear being discovered and are frequently forced to take risks. Paranoid personalities cannot deal with this degree of stress.

Mind: What role does trauma—personal humiliation and suffering—play in the making of a terrorist?
Horgan: Horrific experiences make people more receptive to radical thinking, but [whether such a mind-set develops] depends on how these experiences are interpreted. Close relatives and the person's environment can influence this.

Mind: Psychoanalysts often attribute violence to psychological injuries in early childhood. This was said of left-wing radicals during the 1970s and 1980s who came from well-to-do backgrounds.
Horgan: This factor has been vastly overrated. Terrorist groups offer their members the potential for constructing an ideal and fulfilling a mission. This appeals to young people generally. Once they find themselves in a particular scene, group dynamics often take care of the radicalization. First comes the community, then the ideology.

Mind: Tell me about your latest project.
Horgan: We are studying terrorism dropouts, former activists from about a dozen organizations in Europe, Asia, South America and the Middle East. We ask them about their experiences in the terrorist scene and how they managed to extricate themselves. Researchers have long investigated how people came to be terrorists, but I believe it may be more fruitful to talk with people who turned away from this path.

Mind: Why?
Horgan: You don't become a terrorist overnight. The social milieu in which a person grew up and the internal structure of the radical groups themselves exert a tremendous influence. Such social frames may only become obvious to a person in hindsight.

and unimportant. As one of the prisoners interviewed by Post's team declared: "An armed action proclaims that I am here, I exist, I am strong, I am in control ... I am on the map."

In some societies, social pressure comes into play. When asked why they joined, many of Post's interviewees responded that everyone was doing it and not to belong would mean ostracism. Psychologist John Horgan of Pennsylvania State University spoke to one ex-activist who had a similar explanation: "I just sort of slid into it; I had the feeling I was being sucked in by the group."

In addition to providing a sense of community and power, a terrorist organization can provide a means of vengeance for past humiliations. "What drives people to such acts of violence is a long history of humiliation and an overwhelming desire for revenge," opines Palestinian psychiatrist Eyad El-Sarraj, who directs the Gaza Community Mental Health Program. Many suicide bombers during the second intifada from 2000 to 2005, El-Sarraj says, had watched family members being killed, beaten and humiliated.

More than 70 percent of some 900 Muslim young people in the Gaza Strip interviewed by psychologist Brian K. Barber of the University of Tennessee had suffered severe trauma during the first intifada from 1987 to 1993. Many of these teenagers had been tear-gassed by Israeli soldiers or had experienced attacks while in school or at home. Studies of the backgrounds of other terrorists also indicate that trauma was the most important reason driving them into the underground movement.

In other cases, family strife may be a more significant factor. Criminologist Lorenz Boellinger of the University of Bremen in Germany and his colleagues probed the backgrounds of 250 people who had been suspected or convicted

COURTESY OF JOHN HORGAN

Mind: How do you meet ex-terrorists?
Horgan: Almost all terror groups have a legal political arm [that can be contacted]. I also get tips from officials and journalists.

Mind: What about active terrorists?
Horgan: I find it problematic to interview such people at all. They are so mired in twisted ideas that their statements are either self-serving or have a political aim. It also crosses my own ethical boundaries to get together with people who plant bombs and kill people.

Mind: Do terrorists lead their lives underground, isolated from family and friends?
Horgan: No. In most cases, being a terrorist is not a full-time job. Most terrorists go to work and have family and friends. The people who find their way onto wanted posters are a distinct minority.

Mind: What role do women play in terrorist groups?
Horgan: Women were often frontline members of the RAF or Red Brigades. Today many terrorist groups appear to be much more chauvinistic. Yet some, such as the Tamil Tigers [militant secessionists in Sri Lanka], send women on terrorist missions—for example, the assassination of former Indian prime minister Rajiv Gandhi in 1991—because they are less conspicuous than men.

By profiling terrorists, we will be better able to hunt them down.

Mind: Psychologically, what distinguishes the more recent brand of Islamic terrorism from that of former left-wing radicals?
Horgan: Remarkably little. The Islamists are far more willing to die for their cause, of course, but the psychological attractors, particularly that of group identity, are largely the same. What has changed is the organizational structure. Instead of localizable core groups, we now see transnational and transcontinental networks. Terrorism has become decentralized.

Mind: What can psychological terrorism research do?
Horgan: By profiling terrorists, we will be better able to hunt them down. Although the public sees hardly any difference between a terrorist and a "mere" radical, pursuing political goals by force requires overcoming significant psychological hurdles. Merging the self into the collective is very important in this regard.

Mind: What do you see as the greatest challenge for future research?
Horgan: We really need empirical data against which we can test our theories. Disturbed personalities, victims of life circumstances, social pressure—all of it sounds plausible. But to avoid superficial judgments, we must first get a comprehensive picture of what actually makes terrorists tick.

of terrorist activity—they read trial records and spoke to prison officers as well as to seven of the terrorists themselves. The researchers found that many of the activists had experienced stress early in life from poor family attachments or other social problems. The interviewees seemed to compensate for life's disappointments and feelings of powerlessness by subscribing to a perturbed reality that was starkly defined by friends and enemies.

Turning the Tables

Terrorism is not just about violence, of course. As the name suggests, it is also about fear, as expressed in the Chinese maxim: "Kill one, frighten ten thousand." In many instances, this psychological tactic succeeds all too well: after 9/11, for example, the entire nation experienced high levels of psychological distress, studies have documented.

But now researchers hope to turn the tables on the terrorists. By probing the collective psyches of the terrorist groups themselves, they aim to find new ways to thwart the recruitment of additional group members, to inject dissention into terrorist societies, to facilitate escape from a terrorist life and perhaps to strip group leaders of their powers. By unraveling terrorist bonds, such tactics could eventually put a halt to many heinous crimes. M

(Further Reading)

- **Soldiers for God: A Study of the Suicide Terrorists in the Moscow Hostage Taking Siege.** Anne Speckhard in *The Roots of Terrorism: Contemporary Trends and Traditional Analysis.* Edited by Oliver McTernan. NATO Science Series, Brussels, 2004.
- **The Psychology of Terrorism.** John Horgan. Taylor & Francis, 2005.
- **The Mind of the Terrorist: The Psychology of Terrorism from the IRA to Al-Qaeda.** Jerrold M. Post. Palgrave Macmillan, 2007.
- The Terrorism Research Center: **www.terrorism.com**
- For a wealth of articles and books on terrorism, go to **www.start.umd.edu/publications/other_pubs.asp#journal_articles**

What "Psychopath" Means

It is not quite what you may think

BY SCOTT O. LILIENFELD AND HAL ARKOWITZ

"VIOLENT psychopath" (21,700). "Psychopathic serial killer" (14,700). "Psychopathic murderer" (12,500). "Deranged psychopath" (1,050).

We have all heard these phrases before, and the number of Google hits following them in parentheses attests to their currency in popular culture. Yet as we will soon discover, each phrase embodies a widespread misconception regarding psychopathic personality, often called psychopathy (pronounced "sigh-COP-athee") or sociopathy. Indeed, few disorders are as misunderstood as is psychopathic personality. In this column, we will do our best to set the record straight and dispel popular myths about this condition.

He is a killer, but does that fact make Tony Soprano a psychopath?

Charming but Callous

First described systematically by Medical College of Georgia psychiatrist Hervey M. Cleckley in 1941, psychopathy consists of a specific set of personality traits and behaviors. Superficially charming, psychopaths tend to make a good first impression on others and often strike observers as remarkably normal. Yet they are self-centered, dishonest and undependable, and at times they engage in irresponsible behavior for no apparent reason other than the sheer fun of it. Largely devoid of guilt, empathy and love, they have casual and callous interpersonal and romantic relationships. Psychopaths routinely offer excuses for their reckless and often outrageous actions, placing blame on others instead. They rarely learn from their mistakes or benefit from negative feedback, and they have difficulty inhibiting their impulses.

Not surprisingly, psychopaths are overrepresented in prisons; studies indicate that about 25 percent of inmates meet diagnostic criteria for psychopathy. Nevertheless, research also suggests that a sizable number of psychopaths may be walking among us in everyday life. Some investigators have even speculated that "successful psychopaths"—those who attain prominent positions in society—may be overrepresented in certain occupations, such as politics, business and entertainment. Yet the scientific evidence for this intriguing conjecture is preliminary.

Most psychopaths are male, although the reasons for this sex difference are unknown. Psychopathy seems to be present in both Western and non-Western cultures, including those that have had minimal exposure to media portrayals of the condition. In a 1976 study anthropologist Jane M. Murphy, then at Harvard University, found that an isolated group of Yupik-speaking Inuits near the Bering Strait had a term (*kunlangeta*) they used to describe "a man who … repeatedly lies and cheats and steals things and … takes sexual advantage of many women—someone who does not pay attention to reprimands and who is always being brought to the elders for punishment." When Murphy asked an Inuit what the group would typically do with a *kunlangeta,* he replied, "Somebody would have pushed him off the ice when nobody else was looking."

The best-established measure of psychopathy, the Psychopathy Checklist-Revised (PCL-R), developed by

Superficially charming, psychopaths tend to make a **good first impression** and may seem remarkably normal.

COURTESY OF SCOTT O. LILIENFELD (*top*); COURTESY OF HAL ARKOWITZ (*bottom*); GETTY IMAGES (The Sopranos)

University of British Columbia psychologist Robert D. Hare, requires a standardized interview with subjects and an examination of their file records, such as their criminal and educational histories. Analyses of the PCL-R reveal that it comprises at least three overlapping, but separable, constellations of traits: interpersonal deficits (such as grandiosity, arrogance and deceitfulness), affective deficits (lack of guilt and empathy, for instance), and impulsive and criminal behaviors (including sexual promiscuity and stealing).

Three Myths

Despite substantial research over the past several decades, popular misperceptions surrounding psychopathy persist. Here we will consider three of them.

1. All psychopaths are violent. Research by psychologists such as Randall T. Salekin, now at the University of Alabama, indicates that psychopathy is a risk factor for future physical and sexual violence. Moreover, at least some serial killers—for example, Ted Bundy, John Wayne Gacy and Dennis Rader, the infamous "BTK" (Bind, Torture, Kill) murderer—have manifested numerous psychopathic traits, including superficial charm and a profound absence of guilt and empathy.

Nevertheless, most psychopaths are not violent, and most violent people are not psychopaths. In the days following the horrific Virginia Tech shootings of April 16, 2007, many newspaper commentators described the killer, Seung-Hui Cho, as "psychopathic." Yet Cho exhibited few traits of psychopathy: those who knew him described him as markedly shy, withdrawn and peculiar.

Regrettably, the current (fourth, revised) edition of the American Psychiatric Association's *Diagnostic and Statistical Manual of Mental Disorders Text Revision* (*DSM-IV-TR*), published in 2000, only reinforces the confusion between psychopathy and violence. It describes a condition termed antisocial personality disorder (ASPD), which is characterized by a longstanding history of criminal and often physically aggressive behavior, referring to it as synonymous with psychopathy. Yet research demonstrates that measures of psychopathy and ASPD overlap only moderately.

Serial killer Ted Bundy (*above*) displayed certain psychopathic traits, such as lack of empathy, but most serial killers are not psychopaths.

2. All psychopaths are psychotic. In contrast to people with psychotic disorders, such as schizophrenia, who often lose contact with reality, psychopaths are almost always rational. They are well aware that their ill-advised or illegal actions are wrong in the eyes of society but shrug off these concerns with startling nonchalance.

Some notorious serial killers referred to by the media as psychopathic, such as Charles Manson and David Berkowitz, have displayed pronounced features of psychosis rather than psychopathy. For example, Manson claimed to be the reincarnation of Jesus Christ, and Berkowitz believed he was receiving commands from his neighbor Sam Carr's dog (hence his adopted nickname "Son of Sam"). In contrast, psychopaths are rarely psychotic.

3. Psychopathy is untreatable. In the popular HBO series *The Sopranos*, the therapist (Dr. Melfi) terminated psychotherapy with Tony Soprano because her friend and fellow psychologist persuaded her that Tony, whom Dr. Melfi concluded was a classic psychopath, was untreatable. Aside from the fact that Tony exhibited several behaviors that are decidedly nonpsychopathic (such as his loyalty to his family and emotional attachment to a group of ducks that had made his swimming pool their home), Dr. Melfi's pessimism may have been unwarranted. Although psychopaths are often unmotivated to seek treatment, research by psychologist Jennifer Skeem of the University of California, Irvine, and her colleagues suggests that psychopaths may benefit as much as nonpsychopaths from psychological treatment. Even if the core personality traits of psychopaths are exceedingly difficult to change, their criminal behaviors may prove more amenable to treatment.

Psychopathy reminds us that media depictions of mental illness often contain as much fiction as fact. Moreover, widespread misunderstandings of such ailments can produce unfortunate consequences—as Tony Soprano discovered shortly before the television screen went blank. **M**

SCOTT O. LILIENFELD and HAL ARKOWITZ serve on the board of advisers for *Scientific American Mind*. Lilienfeld is a psychology professor at Emory University and Arkowitz is a psychology professor at the University of Arizona. Send suggestions for column topics to editors@SciAmMind.com

(Further Reading)

- **The Antisocial Personalities.** David T. Lykken. Lawrence Erlbaum, 1995.
- **Without Conscience: The Disturbing World of the Psychopaths among Us.** Robert D. Hare. Guilford Press, 1999.
- **Unresolved Controversies concerning Psychopathy: Implications for Clinical and Forensic Decision Making.** John F. Edens in *Professional Psychology: Research and Practice,* Vol. 37, No. 1, pages 59–65; February 2006.
- **Handbook of Psychopathy.** Edited by Christopher J. Patrick. Guilford Press, 2007.

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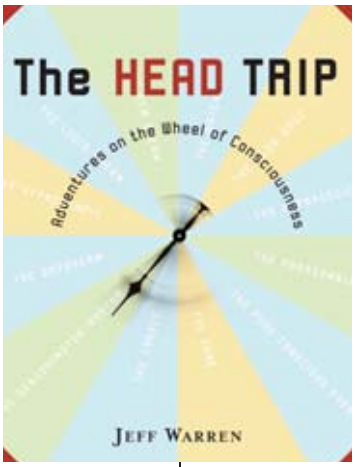
Mind Reviews

> IN THE ZONES

The Head Trip: Adventures on the Wheel of Consciousness

by Jeff Warren. Random House, 2007 ($24.95)



Jeff Warren spent several summers planting trees in northern Ontario, during which he frequently experienced something very odd. He would grab his shovel and start digging at 9 A.M., but when he would raise his head the sun would have moved to the other side of the sky and his watch would show 2 P.M.—and he would have no memory of the past five hours. The phenomenon got him thinking about awareness, and he embarked on a quest to find out as much as he could about the different versions of what we call consciousness.

He describes his wild journey in *The Head Trip,* in which he shows that there is a lot more to consciousness than simply being asleep or being awake. Warren introduces 12 distinct states of consciousness, ranging from well-known phenomena, such as the dreams of REM sleep, to more obscure experiences, such as the trance. He attempts to tie the different states together by likening them to the wedges on a roulette wheel representing the brain, spinning under the power of our biological clocks, but the metaphor seems arbitrary and does not add any insight to this otherwise stellar book.

Warren's hilarious writing makes the nearly 400 jam-packed pages a fun and entertaining read. He defines experiences such as "the Zone," a state that reflects the "absolute integration of body and mind." Athletes reach the Zone by repeating the same motions until the brain, like the muscles, "performs fluidly." Besides this alert and responsive "high," there is also the "numb end of the Zone" that one can arrive at, for example, through hours of planting trees.

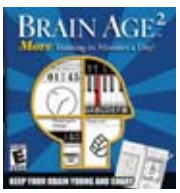
Using dozens of interviews with a wide range of scientists, Warren paints a picture of the current scientific understanding that underlies each state. But the real strength of *The Head Trip* is that Warren gives firsthand accounts of what it means to experience each variant of consciousness. He went to great lengths to understand how the mind changes throughout the day—by living in an isolated cabin for several weeks with no artificial light, for example, he arrived at a sleep pattern that some scientists say is the natural preindustrial rhythm. After going to bed at sundown, he would awaken to "the Watch," a "pleasant meditative state" sandwiched between two bouts of sleep.

The Head Trip opens the reader's eyes to what it really means to wake, sleep and dream; it is "a trip into our own wheeling heads."

—Nicole Branan

Wish List The holiday season has arrived—and what better way to celebrate than with brainy gifts?

>> Winner of a Mensa Select seal, this party game inspires creative and comic wordplay with a premise as simple as comparing **"Apples to Apples."** Players exercise their Broca's area as they find new ways to connect words and try to convince one another why, for example, describing a cactus as "intelligent" makes perfect sense. *www.otb-games.com/showcase/apples.html*



>> Give a brain you love an even more targeted workout with Nintendo's **"Brain Age²,"** a surprisingly fun variation of the several video games, computer programs and Web sites recently unveiled in response to the ever growing body of research showing the importance of regular mental training. *www.brainage.com*

>> For the serious brain enthusiast, an anatomically correct **brain model** makes a great toy, educational tool or office decoration. Find models suitable for any age, budget and level of expertise at *www.anatomysource.com*

>> ***Human: The Definitive Visual Guide*** is a neuroscience primer, a showcase of the world's cultures and an ode to humanity all rolled up into a beautiful coffee table book. Perfect for everyone who loves learning about people, from photography buffs to amateur sociologists. *Edited by Robert Winston and Don E. Wilson. DK Adult, 2006 ($24.95)*

>> *SciAmMind* columnist Vilayanur S. Ramachandran's research comes to life in NOVA's ***Secrets of the Mind,*** which focuses on his work with patients who have unusual abilities or defects in their sensory systems. This 2001 documentary remains intriguing and thought-provoking, even as it is quickly becoming a classic. *www.pbs.org/wgbh/nova/mind*

Compiled by Karen Schrock and Peter Sergo

DO UNTO OTHERS

The Neuroscience of Fair Play: Why We (Usually) Follow the Golden Rule

by Donald W. Pfaff. Dana Press, 2007 ($20.95)

By now most people agree that altruism makes sense in evolutionary terms—a selfless act can allow close relatives to pass on the family genes or inspire those who have been helped to return the favor. But an evolutionary rationale is not a neurological explanation. What is going on in our head when we behave altruistically?

Donald W. Pfaff, a neurobiologist at the Rockefeller University, thinks he has the beginnings of the answer. In *The Neuroscience of Fair Play* he describes the brain pathways that he believes swing into action when humans decide to do something selfless.

Part of his explanation is that altruism arises from some of the same neural mechanisms that evolved to make us love and care for our children. As we developed into social animals, some of this nurturing neural circuitry may have been recruited to make us feel good about helping other people as well.

But Pfaff also puts forth a more unusual hypothesis—he thinks that altruism happens because on a neurological level we "blur" our own identity with that of another person. Empathy and altruism arise, then, because helping others "feels" to our brain like helping ourselves.

This new theory is elegant in that it eliminates the need for complex altruism circuits in the brain. It only requires that existing neural circuits—the ones responsible for sense of self and recognition of others—somehow have to lose a little bit of information at the right time.

> "I believe that we are wired to behave in an ethical manner toward others, and they toward us."

Pfaff outlines many possible mechanisms for this blurring of identity. For instance, he points to the amygdala, a part of the brain that helps us recognize and react to fearful situations and that may also play some role in our recognition of others. Neurons in the amygdala are activated when rats see other rats receiving a painful electric shock. This confluence makes the amygdala an attractive candidate for what Pfaff calls the "ethical switch," which determines whether we behave with empathy.

Pfaff admits there is a lot about his ideas still unanswered. He has succeeded, however, in advancing a testable theory that he and other neuroscientists can start to untangle in the lab. If he is right, it could turn out that the Golden Rule isn't merely a religious teaching. It could be encoded in the very circuitry of our brains. —*Kurt Kleiner*

BOY IN A SUIT

Today's Man

For local screenings, TV listings and DVD info, visit http://orchardpictures.com

Dressed in a new tan suit, Nicky Gottlieb haphazardly decorates his own 21st birthday cake with his fingers. "Physically I'm a man," he explains in his sister Lizzie Gottlieb's documentary, *Today's Man.* "But mentally and emotionally, I'm a boy." This boy can list every Easter date in the last century, calls Mr. Rogers his mentor and is socially limited by Asperger's syndrome. Nicky and other adults afflicted with this high-functioning variant of autism have stumbled through life unable to read others' feelings and body language, hampered by misdiagnoses and few resources. Only in recent years have professionals begun to recognize the syndrome.

In the film, Lizzie chronicles her brother's few attempts to live as an adult—he gets fired on his first day in the mailroom at Chase bank and briefly moves into his own apartment, only to return home to his parents and a full schedule of television. Sitting in a sandbox with Lizzie's two toddler sons, the grown siblings talk candidly about what will become of Nicky when his parents can no longer shave his beard and remind him to wash his hair. When Lizzie wonders what her role will be in this future, the unstated assumption is that someday she will be mothering three boys.

Hope—which is repeatedly crushed in this story—survives at last when Nicky attends a meeting for adults with Asperger's and strikes up an awkward, endearing exchange with a young woman who also has the syndrome. She may not look like his favorite television star Heather Locklear, but she calls to Nicky's mind a Mr. Rogers lesson he holds dear: "She doesn't have to be fancy on the outside; she can be fancy on the inside." —*Corey Binns*

STRAIGHT FROM THE SOURCE

Innovators in Neuroscience

Podcast at www.neuroscene.com

Science rarely seems more quirky, controversial or exciting than when a passionate expert is telling the tale. The NeuroScene podcast series provides a forum for these experts to discuss their ideas and opinions about cutting-edge topics in neuroscience, from the medical benefits of virtual reality to the problems with drug research for Alzheimer's.

Tune in to relaxed chats between leading scientists and NeuroScene's founder and host, Stephen Hernan. In candid discussions, guests clearly explain the machinery of the mind in meaningful contexts such as medicine or health policy. Learn about the blood-brain barrier, for instance, and how its protective job as a largely impenetrable wall creates an obstacle for drugs that could treat brain ailments.

To successfully connect brain processes with daily life, Hernan usually stretches the single-topic podcasts to 20 or 30 minutes. But even if you are an impatient listener, the conversation will likely touch on at least one issue of personal interest, making it worth your while to stick around. When enthusiastic scientists offer their insights on matters they care about, it's hard not to listen. —*Peter Sergo*

askthe**Brains**

Why do we dream?

—Christina Zuniga, via e-mail

Psychologists **Gerhard Kloesch** of the Medical University of Vienna and **John P. Dittami** of the University of Vienna explain:

PUT SIMPLY, dreams are the by-products of neurological processes associated with sleep. But is that the end of the story, or does dreaming serve a purpose? Scientists have not yet discovered whether dreaming has a vital biological function, but we have many theories about where dreams originate in the brain and how we can use them in daily life.

Dreams are tightly linked to phases of sleep that have defined roles in neural maintenance and restructuring, physiological regulation of functions such as metabolism, and information processing associated with cognition. Shorter dreams also occur in the daytime. Most dreaming at night occurs during rapid eye movement (REM) sleep, which is governed by the pons—a region in the brain stem responsible for relaying messages in the brain. Excessive activity in the pons generates random images and information based on memory stores. In addition, some research indicates that newly learned information is consolidated into our memory during REM sleep, which could explain why we often dream about our recent experiences. A related theory maintains that the function of dreams is to clear the brain of its excess baggage—for example, by deleting unnecessary memories. And some experts believe that dreams are a primitive form of thinking and representation associated with subconscious or even psychotic thought.

Dreams linger as our brains make the transition from one state to another (unconscious to conscious). They maintain emotional salience and hence can be used as a positive or negative reinforcement. People can train themselves to recall dreams more frequently and to use them as a conditioning process to become, for instance, braver or more creative.

Dreams are an expression of our physiological, cognitive and emotional underpinnings—with effects that are dependent on each unique situation and individual.

Newly learned information is consolidated into our memory during REM sleep, which could explain why we often dream about our recent experiences.

I heard that the chimpanzee brain is evolving more quickly than the human brain. If humans are evolving at a slow rate, are we in trouble?

—Carlos Navarro, via e-mail

Genetics researcher **Michael Oldham** of the University of California, Los Angeles, responds:

EVEN THOUGH our understanding of humankind's closest living relative has increased considerably in recent years, evolution remains a tricky subject to study in the lab. As a result, the premise of your question—though interesting and certainly possible—has not been established.

The human brain is about three times larger than that of the chimpanzee. This size difference is primarily the result of the massive expansion of the human cerebral cortex that has occurred over the past 2.5 million years. In this time frame, the human brain has certainly experienced more obvious changes than the chimp's has (suggesting that *our* brains are evolving faster).

Recently, however, completion of the human and chimpanzee genome sequences has ushered in a new wave of comparisons between the species based on DNA sequence and patterns of gene expression—how and when a gene's coded instructions are carried out. Genes are expressed in different tissues at different times, so scientists have begun coupling comparisons of human and chimp DNA sequences with comparisons of gene expression in each species' brain. Some researchers have found evidence that mutations in human genes are accumulating faster than in chimp genes, but one recent study found just the opposite (likely forming the basis for your question).

Such findings are provocative and exciting, but it is important to note that there are different ways of estimating evolutionary rates based on these molecular changes. Only when they all start pointing to the same conclusion can we feel confident in our inferences about the evolution of the brain.

With all these caveats in mind, let me answer the question posed. Are we in trouble? Although we cannot completely discount the possibility that chimpanzee overlords may one day wreak terrible vengeance on us for our crimes, another scenario is far more likely: it is the chimps who will disappear—and soon. Wild populations of chimps are predicted to vanish from Africa within the next 50 years as a result of human activities. So, no, we are not in trouble. It is the chimps that are in trouble. M

Have a question? Send it to editors@SciAmMind.com

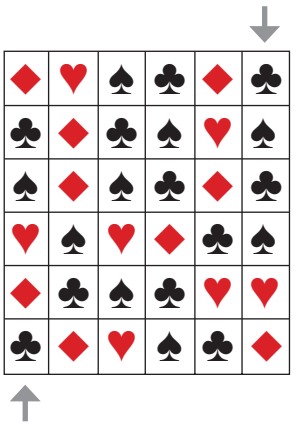
COURTESY OF GERHARD KLOESCH, JOHN P. DITTAMI AND MICHAEL OLDHAM

Head Games

Match wits with the Mensa puzzlers

1 CLUB HOPPING

Find the longest path from the club symbol in the bottom left corner to the club in the upper right corner, always moving in this order: club, diamond, heart, spade. You may not move diagonally or return to a square through which you have already passed.



2 BRAIN SCAN

Starting at any letter and moving horizontally or vertically one space at a time, find how many different paths spell out the word "brain."

B	R	A	I	N
R	A	I	N	I
A	I	N	I	A
I	N	I	A	R
N	I	A	R	B

3 ALGEBRETICAL ORDER

In the eight-term sequence (A, B, C, D, E, F, G, H), the sum of any three consecutive terms is 16. If B = 9 and F = 2, determine the value of D.

4 CUBIC DEDUCTION

Each letter of the alphabet occupies one block of this 3 × 3 × 3 cube (there is no block in the center of the cube). What letter belongs on the blank block, and what color should it be?

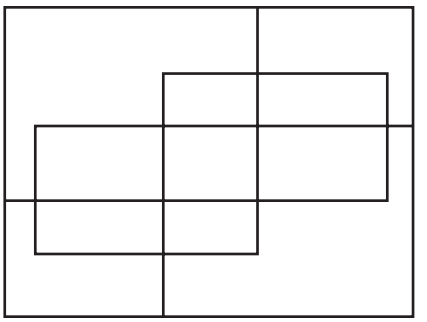
5 ANIMAL TRACKS

Fill in the blanks to make animal names. Blanks in the same column use the same letter.

T I _ _ _
_ _ _ B I _
_ I _ _
_ _ A G _ _
_ _ M I _ _
_ _ W T

6 SHAPE SIFTER

How many rectangles of any size are formed by the lines in this diagram? (Wherever two lines meet in the diagram, they meet at right angles.)

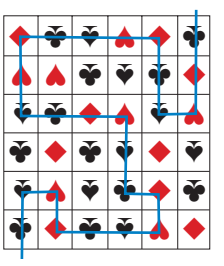


7 FUN FACTOR

The number 6 is the smallest number that has exactly four factors: 1, 2, 3 and 6. The number 12 is the smallest number that has exactly six factors: 1, 2, 3, 4, 6 and 12.

What is the smallest number that has exactly 100 factors?

Answers



1.

2. 32.

3. D = 5. Any sequence with a constant sum must repeat itself. B = 9, so we can deduce that E = 9, because B + C + D = 16 and C + D + E = 16. B and E must have the same value. Similarly, because F = 2, we can conclude that C = 2. We now have C + D + E = 16, with C = 2 and E = 9. Therefore, D = 5.

4. The color is blue, and the letter is "N." (Letters run front to back in 3 × 3 grids. Colors cycle through yellow, blue, red, green, orange and purple, starting at "A" and moving front to back on the top 3 × 3 grid, back to front on the middle 3 × 3 grid, and front to back on the bottom 3 × 3 grid, ending with "Z.")

5. TIGER, GERBIL, LION, ONAGER, ERMINE, NEWT.

6. 24.

7. 45,360.

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