

SCIENTIFIC AMERICAN **MIND**

THOUGHT • IDEAS • BRAIN SCIENCE

August/September 2006

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THOUGHT • IDEAS • BRAIN SCIENCE

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Challenging Choices

By age five or six, a child's brain is 90 percent the size of an adult's, and for a long time scientists thought that the organ's significant structural growth ended by around 12 years old. Recent research, however, shows that an adolescent's brain makes dynamic changes around that age as well as during all of the teen years. As Leslie Sabbagh explains in our cover story, "The Teen Brain, Hard at Work," beginning on page 20, areas involved in planning and decision making experience a spurt of growth at 11 or 12 years and then undergo pruning and reorganization through the early 20s.

That is why, when faced with complex choices under time pressure, the immature cognitive systems can overload, sometimes with catastrophic results. "It's not just that one thing goes wrong," a frustrated parent of two teenagers recently grouched to me. "It's that an astonishing chain of bad decisions can occur at the same time." While parents wait for nature to take its corrective course, at least they can take comfort in knowing that sheer rebelliousness is not solely to blame.

The cool head and decisive analytical thinking that come with experience are key when a brain surgeon faces difficult choices. In her article, neurosurgeon Katrina Firlik discusses how to handle some exceedingly delicate parts of the job. No, not the surgery itself: how to assess the risk of any given procedure and what to tell the patient about it—and when. Turn to page 40 for "Should We Operate?"

Companies that have decided to diversify also need to make appropriate choices, or else intergroup conflict could fracture employees' team performance. What can managers do to best help individuals collaborate? The first step is to determine what type of task the team should accomplish; the next is to match the people to that mission. Hint: hidden aspects of diversity—such as education and experience—sway collective performance more beneficially than obvious factors such as ethnicity, race, gender or age. Psychologists Elizabeth Mannix and Margaret A. Neale explain why in their feature article, "Diversity at Work," starting on page 32.

Mariette DiChristina
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COVER IMAGE BY JEAN-FRANCOIS PODEVIN

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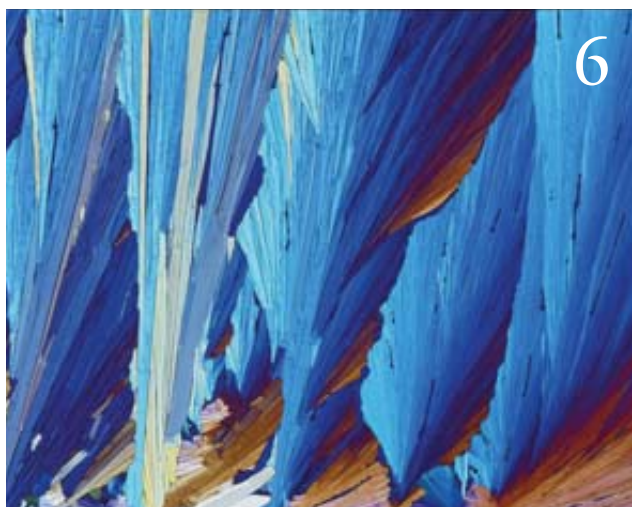
By marrying psychology with archaeology, scientists are unearthing how thought evolved.

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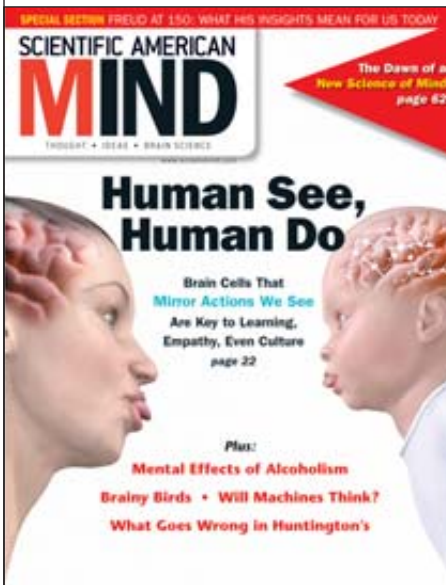
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MIRROR MIMICRY

I am trying to comprehend the existence of mirror neurons in “A Revealing Reflection,” by David Dobbs. More specifically, how can one differentiate between a normal neuron and a mirror neuron? What would the ratio be between the two? Would the ability to recall and replay memories be greater in those who have more mirror neurons versus those who have fewer?

John Spaine
via e-mail

DOBBS REPLIES: Mirror neurons are all premotor neurons—that is, specialized neurons in the cortex that fire to activate motor neurons, which in turn send signals to muscles to contract, relax or whatnot. Although the term “mirror neurons” seems to have taken, I think it more helpful to speak of “neuron mirroring,” because what has been discovered is not a new type of neuron but a new activity and function in premotor neurons, which have already been heavily studied.

As premotor neurons, mirror neurons account for only a tiny percentage of all neurons in the brain. No one knows yet whether all premotor neurons serve a mirroring function. And no one knows whether some people have a lot more mirror neurons (or neuron mirroring) than others. Some studies, however,

suggest that a lack of neuron mirroring produces problems in learning, empathy and perhaps memory. The article, for instance, mentioned that preliminary research suggests that autistic children show less neuron-mirroring activity in brain scans than nonautistic children do. Such a deficit might be either cause or effect of autism, but the link seems significant, and it stands to reason that if mirror neurons play as big a role in learning, social understanding and empathy as the leading researchers think they do, a lack of them would put you at a disadvantage.

You can find musings by leading researchers on these issues at an online forum on mirror neurons at the European Science Foundation Web site. Go to www.interdisciplines.org/mirror

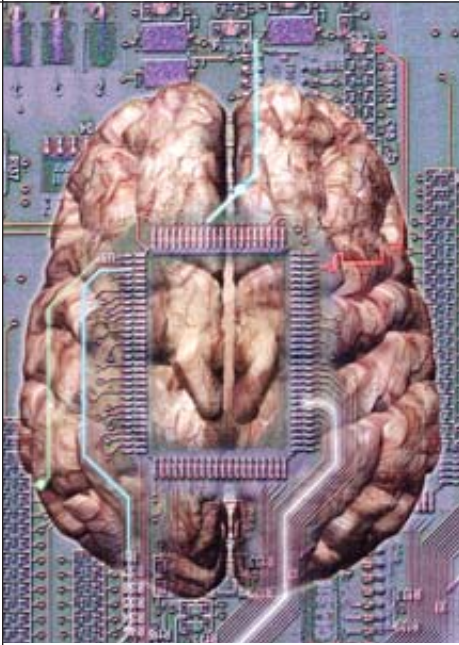
BRAINY MACHINES?

As Yvonne Raley notes in her article “Electric Thoughts?” computers and human brains both process information. Yet the mechanics, speed and reason for doing so are wildly divergent. Ask the average human to add 50 pairs of six-digit numbers; it will take at least 30 minutes, and there is bound to be at least one error. My computer can do that in microseconds, flawlessly.

But a computer cannot compose a letter, enjoy listening to Beethoven, scratch an itch on my back, watch three grandchildren at play, or listen in case the soup boils over on the stove. No computer in the world has enough capacity to store my memories, going back well over 65 years. Still, I don’t have to repeat a name several times to my computer at 10-minute intervals to store it.

The computer is a tool; so is a hammer. They may not appear to have much in common, but they share identical IQs. Making a robot in humanoid shape that can learn, communicate and function in humanoid forms is a worthwhile project. Yet thinking is far more complex. It involves not just logic but also emotions, feelings, desires and, most of all, the remembered experiences of a lifetime. Perhaps some-

PHIL SAUNDERS Space Channel Ltd.



Computer designers seek to add brainlike capacities, such as emotions, for thinking machines.

day someone will build a machine that can think, but it will not be a computer. And why bother? It is so much more fun making thinkers the old-fashioned way.

Peter Charters
Kinmount, Ontario

TEETOTALER POWER

Andreas Heinz's article on the mental effects of alcoholism, "Staying Sober," helps us understand the physical basis for why alcoholics have a difficult time overcoming their addiction and why they may find it easier than others to imbibe in the first place. Statements by the author, however, such as "drugs that can reverse the brain's alcohol-altered chemistry may be necessary" and "victims can no longer free themselves from the bottle" help to perpetuate the false stigma that an alcoholic is completely powerless over his or her addiction—a viewpoint that is thoroughly rebutted by the research on the subject, and a belief that when internalized contributes to relapse.

Research has confirmed time and again the ability of people who have such altered brain chemistry to resist addictive behavior, nonetheless. With

enough positive incentives, even the most severe alcoholics can resist a first drink despite severe withdrawal symptoms and will resist a second drink after having had a first. We know that many have overcome their cycle of addictions on their own and without drugs.

We should be compassionate in realizing that the alcoholic struggles with his or her addiction and may be unable to see how to overcome it successfully. But it is going too far to suggest that just because we can now explain to some extent the withdrawal, obsessiveness and pleasure alcoholics experience in terms of brain chemistry, self-efficacy and other life-affirming values are insufficient for avoiding and overcoming addiction.

Given our current state of knowledge, it would be more prudent to consider drugs as a potentially helpful tool, as opposed to being "necessary," as well as to research the mental impact of the aforementioned values that have already proved successful. It may in fact be that such values themselves have a powerful effect on the brain's chemistry, serving both to protect one from slipping into addiction and to reverse the reinforcing chemistry that results from long-term overconsumption.

Ted Melaniul
St. Charles, Mo.

BIRD FOOD

In "Bird Brains? Hardly," Christine Scholtyssek speculates on Alex the parrot's thought process in coining the term "banerry" for apple. Her hypothesis on the association of cherry with apple based on shape and color seems probable. Her hypothesis, however, on banana with cherry based on taste may be oversimplifying Alex's thought process. He may have been thinking more abstractly. A banana

has a white pithy core with a different colored skin. So does an apple.

Jim Buonocore
via e-mail

DIFFERENT ANSWERS

I took the Head Games test. I qualified for Mensa many years ago, and I always like to see if I still have enough smarts to chew gum and walk at the same time (I am 70). I missed three questions, two of which I could not answer and one where I got a different answer.

In question number five, "tapes" does not mean "adheres," at least in any dictionary I have. I came up with a different answer for question seven: all the words contain two vowels except "hurt." Perhaps mine is an easier answer?

I enjoy the test, but perhaps the puzzler, Abbie Salny, has a better dictionary than I do.

Kurt Bramer
via e-mail



Alex the parrot learns to spell with psychologist Irene Pepperberg.

SANFORD/AGLILO Corbis (top); RICK FRIEDMAN Corbis (bottom)

Head Lines



Magnified crystals of estradiol, a form of estrogen that carries signals between neurons.

Surprise: Estrogen as Neurotransmitter

Mounting evidence indicates that members of the estrogen family of sex hormones can morph into neurotransmitters in the brain, fulfilling an unexpected role. The latest study comes from a team at Johns Hopkins University and the University of Liège in Belgium. Researchers manipulated the amounts of estradiol (a form of estrogen) in the brains of quail by injecting a compound that suppresses estradiol production. Within minutes the birds exhibited dramatic changes in sexual activity and pain thresholds. Hormones cannot achieve signaling speeds that fast, says Gregory Ball, a professor of psychological and brain sciences at Johns Hopkins who led the work. Humans have similar molecular mechanisms in their brains.

Estrogens interact with various groups of cells in the body, such as breast and uterus

tissue, and with neurons in the brain. When estrogens act as hormones, they travel through the membrane of a cell to the nucleus, where they switch genes on or off, thereby regulating protein production. The timescale for the resulting effects, such as the stimulation of menstrual cycles, lies on the order of days, months or even years. The neurotransmitter estrogen docks directly to the outer membrane of neurons, initiating direct communication among the cells. The quick firing triggers actions within minutes or seconds.

The discovery of the estrogen signaling system could adjust the prevailing model of how neurons communicate, as well as clinical interventions for certain brain conditions that involve estrogens, Ball says. He notes that estrogens act quickly on pain thresholds and therefore “might be very useful when thinking about pain-control medication.”

—Nicole Branan

A. PASIEKA Photo Researchers, Inc.

Stopping HIV Dementia

Harris Gelbard was doing his residency in pediatric neurology in 1988 when one of his colleagues was diagnosed with AIDS. The man developed every neurological and psychiatric complication in the book: stroke, Parkinson's, paranoia. Then a gripping dementia left the 34-year-old doctor mute and in diapers. He died shortly thereafter.

Since then, Gelbard has spent his career studying how AIDS affects the brain, and he recently discovered what could be the first treatment for HIV dementia: valproic acid, used to treat epilepsy and bipolar disorder.

Although the current AIDS "cocktail" of drugs works to keep virus loads in the body low, the medicines have a hard time getting into the brain. Scientists know that the virus sneaks in early, within days or weeks of infiltrating the body, and then slowly destroys brain cells by attacking certain chemicals, such as glutamate, that are vital to neurons.

Gelbard, a professor of neurology, pediatrics, microbiology and immunology at the University of Rochester, recently reported that valproic acid slows this dementia. The study involved 22 patients with HIV dementia, 16 people with memory problems and six unaffected subjects who served as controls. If larger studies bear out this initial finding, valproic



acid would be the first drug for AIDS dementia, Gelbard says.

Mental symptoms most often reported by today's AIDS patients are more subtle than during the disease's early spread 20 years ago, when full-blown dementia developed in young people rather quickly. Patients now more typically complain of a host of murky neurological problems, including attention deficits, slowed thoughts and problems focusing on daily tasks. "You are 80 percent of yourself," Gelbard explains. As more people survive with the current AIDS cocktail, as many as 20 percent are left with these problems, he says. —*Jamie Talan*

Swept Up in Land Mines

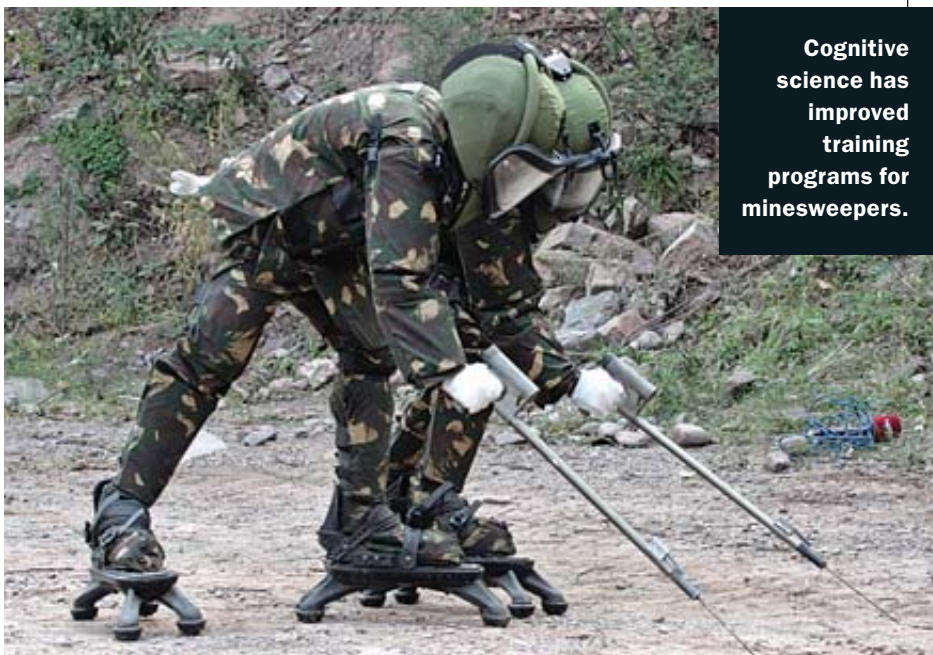
Cognitive scientists don't often get a chance to save lives. This summer James Staszewski will continue to do so.

The U.S. Army originally approached Staszewski, a cognitive psychology professor at Carnegie Mellon University, eight years ago to troubleshoot the training program for personnel who would be detecting land mines in war and peacekeeping zones. Trainees had fared abysmally in exercises, catching only 10 to 20 percent of mock mines. Staszewski had been researching how people acquire exceptional memory and calculation skills. His studies upheld the idea that expertise accrues from experience, so in principle good minesweeping should be teachable. The army paired Staszewski with Vietnam War veteran Floyd "Rocky" Rockwell, who was working with a humanitarian group removing mines in war-torn countries.

Staszewski videotaped Rockwell and a protégé as they swept for dud mines on a training ground at Fort AP Hill, Va. Their detector was essentially a long stick with a magnet on the end that clicks when metal is near. Staszewski recorded the positions of the detector heads, the clicks and the men's voices as they thought out loud. Army instructions recommended sweeping the head above the ground at three feet per second, but the two experts went much slower, a foot per second, floating the detector in overlapping sweeps. Crucially, they did

not just listen to clicks; they built up images in their heads of a suspected object's contours, "prospecting for familiar spatial patterns," Staszewski says.

Staszewski subsequently developed a training system to inculcate these techniques. Combat engineers who spent an extra 12 to 15 hours practicing the new method found simulated mines 85 to 95 percent of the time and detected 97 to 100 percent of defused mines. Staszewski later created a similar method for an experimental army mine detector equipped with radar. Using a more precise camera system to observe accomplished sweepers, he is currently trying to identify small differences that allow the experts to discriminate between mines and debris. —*JR Minkel*



Cognitive science has improved training programs for minesweepers.

Prozac Spurs Neuron Growth ...

Recent work with mice has revealed that the antidepressant Prozac spurs growth of new neurons in the brain. Prozac, or fluoxetine, is thought to ease depression by raising the level of the neurotransmitter serotonin in the brain. But now researchers have learned that the drug also causes more neurons to form than normally would. In mice, blocking this growth nullifies the drug's effects on behavior, suggesting that neuron formation may be part of the mechanism that alleviates depression.

How exactly fluoxetine boosts neuron formation, called neurogenesis, is unclear. Neurogenesis consists of several rounds of cell division that create many neurons from a few

stem cells. To pinpoint fluoxetine's effect on this pathway, a group at Cold Spring Harbor Laboratory on Long Island, N.Y., created a strain of mouse with neural stem cells that contained a green fluorescent protein in their nuclei, making the cells easy to track under a microscope. They found that fluoxetine works on the second stage of neurogenesis, causing cells called amplifying neural progenitors to reproduce at a 50 percent greater rate than usual. This step is therefore "a clear target for the action of an antidepressant," which may help in designing better antidotes, says study leader Grigori Enikolopov.

Investigators can use the mouse model to perform more detailed studies of neurogenesis and its relation to mood and of the effects of other depression treatments. The model "is amenable to a wide variety of pharmaceutical and neuroactive stimulation protocols," says Dennis Steindler, a neuroscience professor at the University of Florida not connected to the research. Enikolopov says he is now studying the drug's effect on neurogenesis in young and pregnant mice, to help assess the risks of antidepressant treatment in human counterparts. Another goal will be to determine whether other depression medications target the same step in neurogenesis. —JR Minkel



... Yet Antidepressants Offer No Cure

Do antidepressants "cure" depression? No, says Joanna Moncrieff, a psychiatrist at University College London—no

more so than insulin "cures" diabetes or alcohol "cures" social anxiety.

Moncrieff, who has published several critical studies of psychiatric drugs in leading medical journals, advocates a "drug-centered" rather than "disease-centered" model for understanding psychoactive medication. "Instead of relieving a hypothetical biochemical abnormality," she says, antidepressants themselves cause "abnormal brain states," which may coincidentally relieve psychiatric symptoms.

As for curing depression, Moncrieff notes that "there are no known drug-induced effects consisting of long-term elevation of mood," nor is there is any evidence that medication corrects a "chemical imbalance," as both pharmaceutical advertising and physicians often claim. These results may explain why, despite much greater use of antidepressants in recent years, there is "little evidence outside of controlled drug studies that long- or short-term outcomes for depression are changing."

Indeed, Moncrieff adds, some studies show that depressive episodes are more frequent and last longer among antidepressant users than nonusers. A drug-centered approach to treating psychiatric conditions, she says, would look at each medication's specific alleviating effects—some act as stimulants or as sedatives, whereas some blunt emotions—rather than labeling any as an "antidepressant" when no drug has been proved to deliver long-term mood elevation.

—Jonathan Beard

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Foot Alert

More than any other cue, the sight of advancing feet alerts humans to the presence of moving creatures, according to researchers from Queen's University in Ontario and Ruhr University in Bochum, Germany. The investigators rendered walking human and animal figures as constellations of white dots on a computer screen (*right*). Volunteers were shown a random sequence of these dot clusters—some in correct anatomical orientation, some upside down, some scrambled—and were asked to determine which direction the “creatures” were walking. Participants tended to become confused with upside-down figures. The reason? The feet. Subjects responded accurately if an upside-down figure had right-side-up feet but did worse if the feet alone were upside down. “It’s only a few dots that convey the information—the dots that connect to the feet,” says study co-author Nikolaus F. Troje, a specialist in biological cybernetics.

To Troje, the result suggests that the visual system may contain a “life detector” attuned to the pattern of feet moving against gravity. “I think it’s a very old system that we probably share with lots of other animals,” he says. In another recent report, newly hatched chicks responded to right-side-up or scrambled dot clusters with correct foot motions but not to inverted figures. Troje speculates that a life detector could explain why cats stalking prey place their feet so deliberately, adding that a foiled detector may underlie phobias of creatures that move without clear footfalls, such as snakes, insects and birds.

—JR Minkel



Which feature is most likely to tell you a creature is moving? The feet.

■ **Epilepsy** isn't the problem for many seizure sufferers. Trauma causes the seizures in up to 30 percent of people diagnosed as epileptic. The most common trigger is anxiety, such as from the onset of a major illness. Wrongly diagnosed, individuals may unnecessarily take epilepsy medication and suffer stigma for years, according to three studies in the June 13 issue of *Neurology*. One distinction: almost all people in a psychological seizure closure their eyes; almost all true epileptics bear seizures with their eyes open.

■ **Teen smoking** has not dropped since states passed laws against tobacco sales to minors. A University of Geneva review of U.S. studies finds that even where laws are enforced and retailers comply, no change in smoking has resulted compared with pre-law days. What works? Cost. When cigarette prices drop, young people are more likely to pick up the habit, according to an independent analysis of Canadian tobacco-tax repeals done by the University of Toronto.

■ **Antipsychotic drugs**, stimulants and antidepressants were prescribed for five times as many children in 2002 than in 1993, according to a new study by Columbia University. The sharp increase concerns certain psychiatrists, who point out that many of the drugs are not expressly approved for children or adolescents and that few data exist on whether they work or on the risks of side effects.

Babies Organize Sight

By the time they are four months old, most babies can organize visual information in at least three ways: by brightness, by shape and by how close together objects are. Emily Farran, a psychologist at the University of Reading in England, tested infants by showing them images on a computer screen while cameras tracked how long they gazed at various patterns. Her results indicate that perception of brightness emerges first, by two months, in line with previous work. By four months, most infants can group objects by shape and proximity, too. “Earlier research had shown only the ability to group by shape at six to seven months,” Farran says, “and we believe we are the first to show grouping by proximity.”

Farran’s interest in the development of visual perception comes from her ongoing research into Williams syndrome. Infants who have the condition have general IQs of about 60, “but their verbal

abilities are far superior to their spatial cognition,” she says. Farran is now using the same tests to see how these skills develop in babies and toddlers with Williams syndrome. “Infants are being diagnosed earlier now, thanks in part to a genetic test,” she says, adding that better tracking of abilities during early development could also help doctors understand and counteract perception impairments observed in adults with the syndrome.

—Jonathan Beard



By four months of age, most babies can group objects by brightness (shown), shape and proximity.

Seeing Alzheimer's Early

One of the daunting aspects of Alzheimer's disease is that it is seldom diagnosed until victims have already lost significant cognitive function. Even if treatments are developed, they will not have sweeping impact unless early-detection methods are devised.

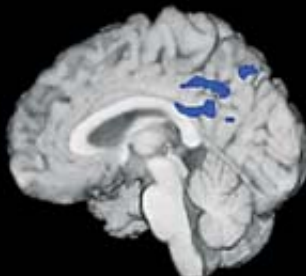
One step toward this grail may come from psychiatrist and brain researcher Eric Reiman of the Banner Alzheimer's Institute in Phoenix. He has been using positron-emission tomography (PET) to study cognitively healthy people at three levels of genetic risk for the disease—those with two copies, one copy or no copies of the *apolipoprotein E type 4* (*APOE4*) gene, which has been implicated in autopsies of Alzheimer's victims. Reiman says that *APOE4* carriers show reduced metabolism in brain regions known to be affected by Alzheimer's disease and that "these reductions become more pronounced over time." He and his colleagues plan to use PET to evaluate high-risk groups as various therapies are undertaken, to try to reveal if a therapy shows any effect. "Our goal is to find an effective way to prevent [Alzheimer's] without having to lose a generation along the way," Reiman says.

Scott Small, a neurologist at Columbia University, is using magnetic resonance imaging to define an early-warning clue in the

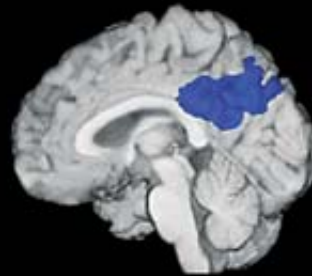
hippocampus, vital to memory. "By imaging Alzheimer's patients over time," he explains, "we have found which parts of the hippocampus have neuronal dysfunction." The pattern of dysfunction in Alzheimer's is different from that in normal aging. "We could use this knowledge both to diagnose [Alzheimer's] in its earliest stages," Small says, "and to test new drugs to see if they arrest cell loss in these special regions."

—Jonathan Beard

Young Adults at Genetic Risk



Alzheimer's Disease



Patients with Alzheimer's have progressively reduced metabolism in certain locations (blue, at right). Cognitively normal young adults who carry a common Alzheimer's susceptibility gene already have reduced activity in the same locations (left), more than four decades before typical onset of symptoms.



Study subjects playing doctors or parents would give a new flu vaccine to others—but not to themselves.

Which Flu Risk Would You Take?

Individuals facing a medical dilemma are more likely to choose a riskier course for themselves than for others.

Researchers at the University of Michigan and the V.A. Ann Arbor Healthcare System asked 2,400 participants in an online study to play one of four roles: a patient deciding on individual treatment, a parent choosing for a child, a physician advising a patient, or a medical director setting guidelines for many patients. The volunteers were then asked to imagine a serious flu outbreak that presented a 10 percent chance of causing death and were given the option to take a new flu vaccine that carried a 5 percent chance of being fatal.

People playing the parent, doctor and medical director roles were all more likely to choose the vaccine than those playing the self-treating role. Responses followed a similar trend

when participants were presented with a cancer scenario and the choice to have chemotherapy or not. The outcomes represent the phenomenon of "omission bias"—choosing inaction over action, even at the risk of greater harm.

Study leader Brian J. Zikmund-Fisher, who holds research positions at the university and the V.A., notes that even though actual patients in recent years have become increasingly involved in making treatment choices, the study emphasizes why clinicians should not become less involved. "There remains an important role for coaching the decision-making process," he says—"helping patients to see the big picture."

Zikmund-Fisher is planning follow-up work that will examine the effect of perspective on decisions made in end-of-life settings, such as choosing symptom-relieving care versus aggressive treatments that could prolong life but at a lower quality.

—Nicole Garbarini



involving either intense sensory stimulation or self-reflection. Surprisingly, report the researchers in *Neuron*, they found a “complete segregation between the two patterns of activity.” They noticed that brain regions active during introspection were largely suppressed during perception, and vice versa. When people are busily sensing or doing something, the region involved in self-monitoring quiets down. In contrast, introspection stimulates regions involved in self-monitoring and suppresses regions active in perception.

These findings counter the claim by some philosophers and neuroscientists that the brain utilizes a type of homunculus, or observer, during self-awareness. The

theory suggests that the prefrontal cortex, which is involved in self-monitoring, and the sensory cortex, active during perception, engage in an interplay that gives rise to subjective awareness and perception—as if part of the forebrain were observing sensory activity in the hindbrain.

Malach and his colleagues argue that the data show otherwise. Converging neurological and psychological evidence, they note, indicates that internal representations of the self are associated with distinct brain structures. Indeed, they believe a distinct neural state underlies the experience of “losing yourself in the act.”

—Richard Lipkin

Lost in the Moment

Athletes find themselves “in the zone.” Professors become “lost in thought.” Meditators get absorbed “in the moment.” Can humans really lose their awareness of self when they are powerfully caught up in an experience? Neurobiologists Ilan I. Goldberg, Michal Harel and Rafael Malach of the Weizmann Institute of Science in Rehovot, Israel, assert there is neural evidence to answer in the affirmative.

The team used functional magnetic resonance imaging to compare brain-activation patterns of nine people engaged in tasks

More Likely to Succumb

Despite the romantic notion that adversity makes a person mentally tough, new research suggests the opposite is true. Investigators at the University of Leicester in England read a narrative describing a bank robbery to 60 volunteers, then asked them to complete a test of their recall of details. The subjects were next asked a series of leading questions designed to elicit wrong answers about the same details. Participants were also told that their original responses may have been wrong and that they were being asked again to see if they would change their tune. Respondents who, according to an earlier questionnaire, had experienced more adversity early in life—including parental divorce or death, illness or bullying—were more likely to bow to suggestion or pressure and change their original, correct answers.

Negative experiences may encourage suggestibility by eroding a person’s confidence in his or her judgment, proposes graduate student Kim Drake, one of the researchers. Drake hopes to develop ways to counteract suggestibility, in part to prevent false confessions to crimes.

—JR Minkel



People who suffered past adversity were less certain of their answers on a memory test.

Champ Chimp

A chimpanzee's development of number skills sheds some light on our own

BY MICHAEL SPRINGER



Even when the numbers are covered quickly by white boxes, Ai can sort them accurately.

WHEN AI PRESSES the touch-sensitive computer screen, the Arabic numerals 1, 3, 5, 7 and 9 pop up in random order. She correctly taps the numbers in ascending order, earning a handful of raisins as a reward. Ai, a chimpanzee, also reveals a lightning-fast short-term memory for numbers. When white boxes mask the numerals right after each is displayed, she still strikes the boxes accurately—unlike

some of the human volunteers who take the test.

Ai's videotaped demonstration, at a recent conference, is the culmination of two decades of work by Japanese researcher Tetsuro Matsuzawa of Kyoto University. Matsuzawa has been training and observing Ai since 1978. Ai proved to be a star pupil, and she and Matsuzawa get together almost daily for a mixture of play and

research. The 30-year-old chimp participates enthusiastically—as does her six-year-old son, Ayumu.

Humans can easily memorize small chunks of information, such as strings of numbers, a phenomenon that psychologist George A. Miller wrote about in his 1956 landmark paper, “The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Informa-

(She correctly **taps the numbers** in ascending order, earning a handful of raisins as a reward.)

TETSURO MATSUZAWA

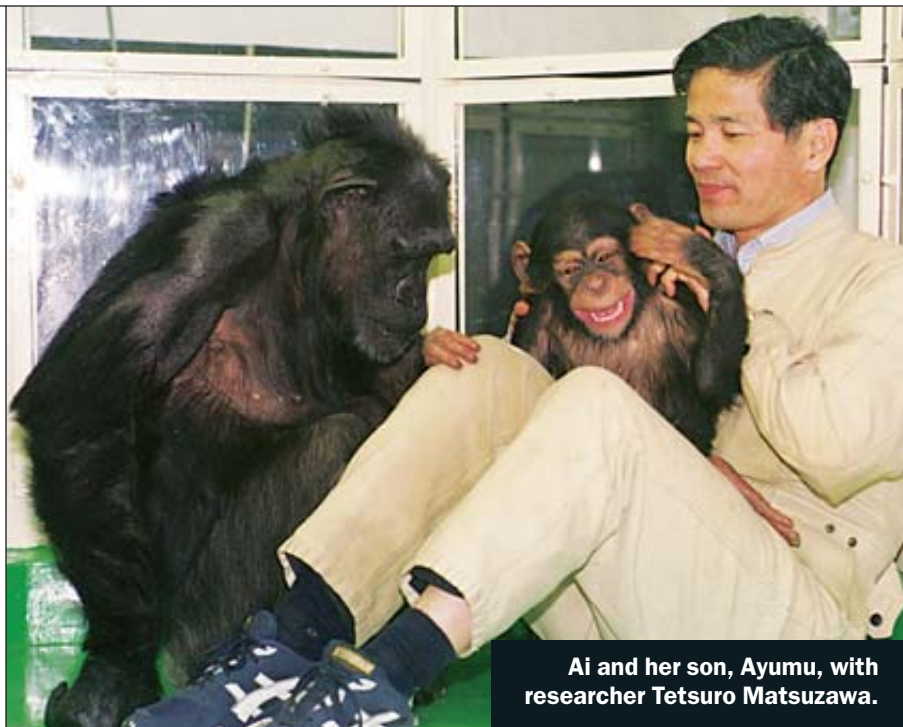
tion.” How might our closest primate relatives develop an understanding of numbers—and what might that process tell us about our own abilities to grasp such abstract concepts? Matsuzawa has sought answers in his work with Ai.

Scientists have long known that in the wild, primates can count to at least three: a single chimp or a pair will always flee if they encounter an unfamiliar chimp while hunting. Only a chimp in a group of at least three members is willing to pick a fight. But coping with larger numbers, represented with abstract numerals, is a far more challenging cognitive task—one that, until now, has been considered the exclusive purview of people.

At the conference, Ai’s videotaped efforts on number-order tests seems unbelievable to the delighted human audience. In the masking trials, she excels: the scientists watching at the conference are barely able to note more than one or two of the numbers before all of them are covered up. In one video, a human tries his hand at the test with the white squares and scores only a few hits. But the ape, working “blindly,” almost always types a sequence of four correctly and even handles five numbers with some accuracy. Another video shows Ai, just after a test begins, becoming distracted by the noise of other chimps fighting. After pausing for 20 seconds to listen, she returns to the screen and then calmly notes and types in all the masked numbers in the correct order.

Math Classes

Behind this steady performance are many years of patient training. First, Matsuzawa taught Ai the meaning of the cardinal number—the correspondence between each number and a quantity of objects. Ai learned to associate a quantity of one to nine objects with the corresponding numeral appearing on the screen. Next, Ai achieved a certain understanding of numerical order, gradually learning that the numbers rise from 0 through 9. Once Ai had grasped that 0 comes



Ai and her son, Ayumu, with researcher Tetsuro Matsuzawa.

before 1 and not the other way around, she was presented with a 2—and so on, one by one, up to 9.

Ai thus can count, but only in a limited sense. She has never appeared to develop the abstract sense of generalization that human children, even at the tender age of three, are beginning to grasp—that for each number that exists there is another, larger one: one plus one is two, two plus one is three, and so on. Ai has only learned to associate each Arabic numeral with a corresponding quantity of objects and to put these numbers in order.

How can Ai, who needed many years of careful teaching to learn the numbers, be so much faster than humans at sorting when the digits appear in random order on the screen? Typing them in, in the correct order, after they flash on the screen one after another for a fraction of a second each, seems to be child’s play to her—although for the audience at the conference, it proved challenging to do.

Matsuzawa believes that numerical abilities in humans came at the expense of other abilities in a kind of

evolutionary trade-off—one between having the skill to quickly note things, on the one hand, and developing more complex cognitive abilities, on the other. For apes in the wild, it is a matter of life and death to take in a number of stimuli simultaneously and arrange them in the right order: over there lurks a leopard, above another chimp swings through the trees, and beneath hangs a piece of ripe fruit. We end up “paying” for our human abilities to grasp abstract quantitative concepts—which are far beyond those of apes—with greatly reduced perceptual abilities.

Human brains are better than those of other primates in artificial environments that are rich in social signals. For people, the focus is on correctly interpreting social signals, avoiding misunderstandings in speech, and making careful calculations in response to any given situation, rather than merely reacting immediately to all the objects we see. **M**

MICHAEL SPRINGER is a freelance science writer in Aachen, Germany.

(Further Reading)

- ◆ **Cognitive Development in Chimpanzees.** Edited by T. Matsuzawa et al. Springer, 2006.
- ◆ Ai’s Web site with additional links: www.pri.kyoto-u.ac.jp/ai/index-E.htm

The Quirks of Constancy

Even when we consciously know two lines are the same length, why can't we help seeing them as different?

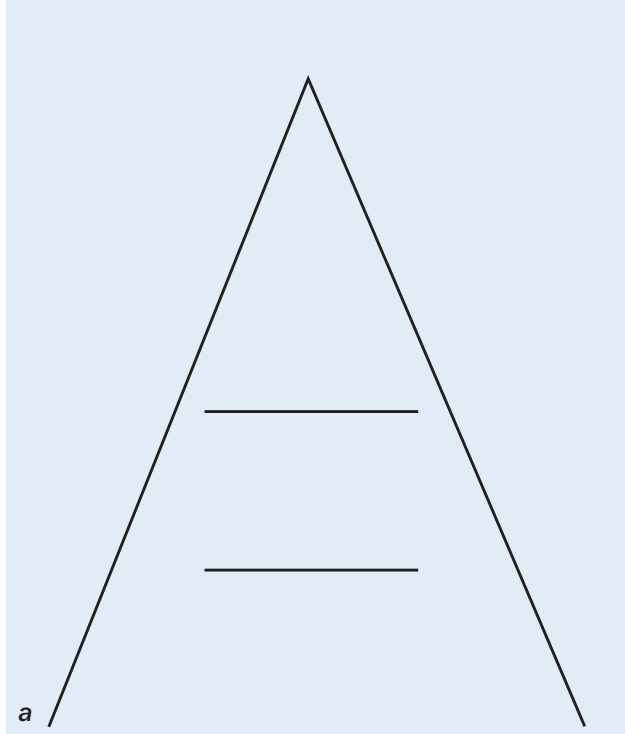
BY VILAYANUR S. RAMACHANDRAN AND DIANE ROGERS-RAMACHANDRAN

ILLUSIONS are anomalies that can reveal clues about the mysterious workings of the brain to neuroscientists in much the same way as the fictional Sherlock Holmes can solve a crime puzzle by homing in on a single out-of-the-ordinary fact. Think of the phrase “the dog that did not bark” (in Sir Arthur Conan Doyle’s short story “Silver Blaze”) or of the missing dumbbell (in Conan Doyle’s *Valley of Fear*).

Perhaps the most famous examples of such visual tricks are the geometric optical illusions. In the Ponzo illusion (*a*), first demonstrated by Italian psychologist Mario Ponzo in 1913, one horizontal line looks shorter than the other one, although they are identical. In the Mueller-Lyer illusion (*b*, on *opposite page*), created by German psychiatrist Franz Mueller-Lyer in 1889, the line bounded by the diverging arrowheads looks shorter than the one with converging arrowheads—although they, too, are identical.

These illusions are very familiar, yet powerful; knowledge of true line length does not stop or diminish their effect. Do we have any idea what causes them? Why would the visual system persist in committing an error, in perceiving incorrectly something so simple even when we consciously know it is a trick? Before we explore those questions, let us introduce two more eye puzzles.

In *d*, on page 18, we have a field of



shaded disks that are seen as eggs dispersed among cavities. The disks that are light on top look like bumps or eggs, the others like cavities. This sense of depth comes from a built-in tendency for your visual system to assume that light shines from above (after all, we evolved on a planet with a single sun overhead), as we described in an earlier column [“Seeing Is Believing,” *SCIENTIFIC AMERICAN MIND*, Vol. 14, No. 1, 2004]. So the brain interprets the disks that are lighter on top as rounded like eggs and the light-on-bottom ones as cavities (because a hollow would be light on its bottom if lit from above). In *e*, on page 18, the shading gradient changes from left to right, and the depth is far less compelling (the tokens seem flatter)

and more “bistable” (individual disks are equally likely to be seen as convex or concave, and the light source can be seen as arising from either side).

So far so good. But we also noticed that the perceived *gradient* of lightness—the apparent difference in brightness between the lightest and darkest parts of each disk—seems shallower for the spheres than for the craters. The brightness gradient also appears less steep for light-on-top disks than for light-on-side disks. Why? The physical gradient is exactly the same for each of the shaded disks (to convince yourself, rotate the paper).

Constancy Connection

These two sets of illusions, the geometric optical illusions and the gradient steepness type, seem completely unrelated. But both reveal a basic principle in vision called perceptual constancy. This effect is the tendency to observe correctly an object as having constant physical attributes (size, shape, color, lightness, distance and so on) despite tremendously variable retinal images that may occur for that object, which arise from changes in vantage point, distance, illumination and other variables. This point is not trivial. Unlike a video camera, our brains do not merely “read out” the retinal image to perceive an object. Rather we interpret it based on knowledge and context. For instance, constancy guides us despite

(These illusions are **very familiar**, yet powerful; knowledge of true line length does not stop or diminish their effect.)

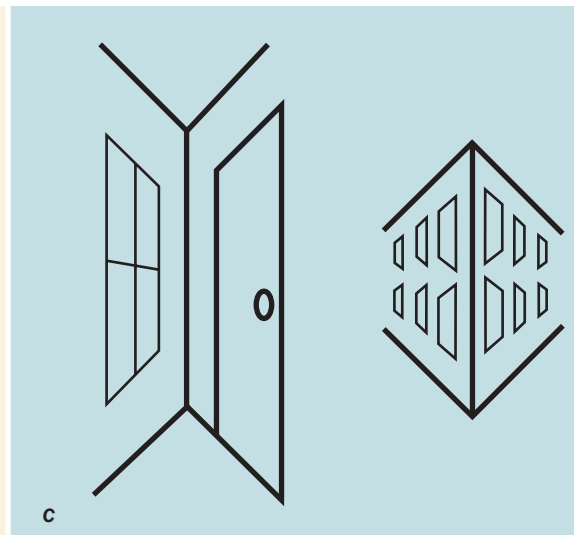
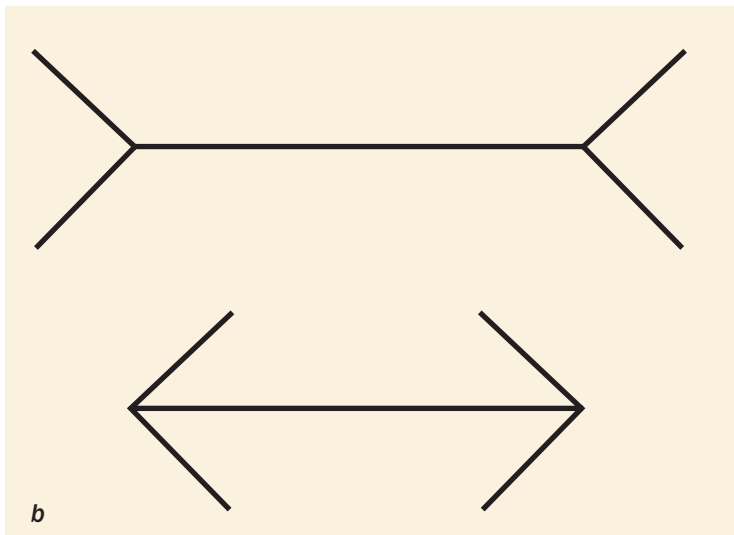
changes in lighting. Believe it or not, the black ink of a newspaper has a higher absolute luminance (the physical light intensity measured by a photometer) when viewed in sunlight than white paper does when viewed in a well-lit room at night [see “Seeing in Black and White,” by Alan Gilchrist; *SCIENTIFIC AMERICAN MIND*, June/July]. Yet we recognize the true character of the objects and their comparative brightness: despite lighting conditions, we experience it as black type on white paper and do not—in fact, *cannot*—perceive the absolute luminances.

Another example, more relevant to our geometric illusions, is size constancy, or the tendency to identify an object as being constant in size whether it is near or far. If you watch a person running toward you, his image on your retina enlarges, although you do not

ject of constant size will throw a smaller image on your retina as it moves farther away. This shrinkage is just a simple consequence of optics; it has nothing to do with perception. Now consider what happens when you stand in the middle of parallel railway tracks and cast your gaze along their length. The rails remain parallel and the ties between them a constant size along their length, yet the resulting retinal image or indeed any 2-D projection, such as a photograph or line drawing, shows the space between the rails and the corresponding size of the ties shortening with increasing distance. Again, this result is from simple optics, not perception. In the perceptual world, our brain largely corrects for this linear perspective, and we interpret the railroad as straight and parallel and the ties as being of a constant size. You

ties, which get smaller with distance). Because they are interpreted in the context of converging lines and appear to lie at different distances, the brain applies a constancy correction, so that the top line looks longer than the bottom one. It is as if the brain reasons: “One horizontal line is farther away, so if it is the same physical length as the other horizontal line it should cast a smaller image in my eye. But because the image is the same size, it must be produced by a longer line that is farther away.” This correction occurs even though the viewer may not have any sense of depth from the converging lines.

Because the top line is deliberately drawn to be the same length as the bottom one, the brain *misapplies* this constancy rule, and you perceive it as looking abnormally long. The exact converse happens for the bottom line;



see him expanding. Your brain unconsciously takes into account the distance and interprets size correctly. Similarly, if a person is lying on the ground with his feet extended toward you, the retinal image of his feet is twice the size of his head, but you do not see a microcephalic with giant feet. You see a normally proportioned person with his feet closer to you than his head.

But how does size constancy explain our geometric illusions? The phenomenon arises from a depth cue, called linear perspective, with which every visual artist is familiar. An ob-

ject of constant size will throw a smaller image on your retina as it moves farther away. This shrinkage is just a simple consequence of optics; it has nothing to do with perception.

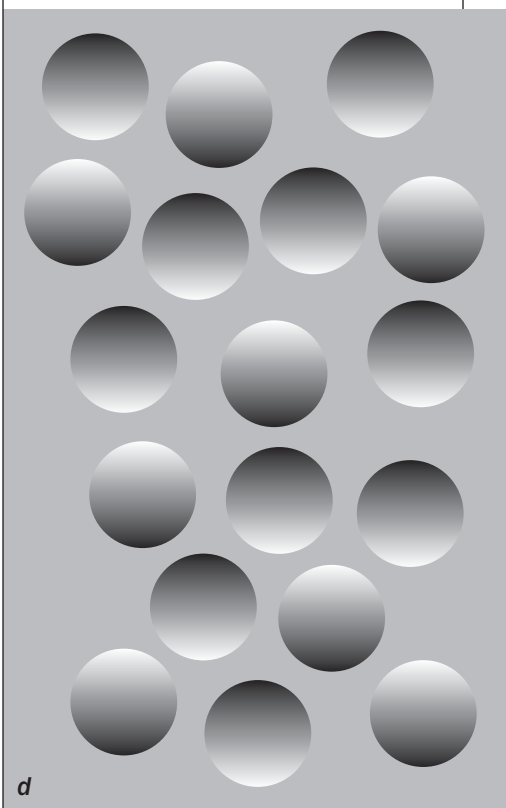
Coming Together

Now take another look at the Ponzo illusion. Consider the converging lines; like railroad tracks, they suggest parallel lines extending far into the distance. Like the railroad ties, the horizontal segments are interpreted in the context of these converging lines and thus are seen to exist at different distances. In the Ponzo illusion, however, the two horizontal segments are drawn to be exactly the same length (unlike railroad

ties, which get smaller with distance). Because they are interpreted in the context of converging lines and appear to lie at different distances, the brain applies a constancy correction, so that the top line looks longer than the bottom one. It is as if the brain reasons: “One horizontal line is farther away, so if it is the same physical length as the other horizontal line it should cast a smaller image in my eye. But because the image is the same size, it must be produced by a longer line that is farther away.” This correction occurs even though the viewer may not have any sense of depth from the converging lines. Because the top line is deliberately drawn to be the same length as the bottom one, the brain *misapplies* this constancy rule, and you perceive it as looking abnormally long. The exact converse happens for the bottom line;

Gregory has also proposed a de-

Why do the top-lit eggs look **more uniform** in surface reflectance (lightness) compared with the side-lit disks?



from above. But why do the top-lit eggs look more uniform in surface reflectance (lightness) compared with the side-lit disks or the bottom-lit cavities? Here we need to invoke the analogous phenomenon of lightness constancy—the ability of the brain to extract the true reflectance of an object’s surface, instead of variations in luminance caused by illumination.

First, consider the light-on-top egg. The brain assumes the sun is above you, and a real egg would convey exactly this pattern of luminance variation—a gradient of luminance decreasing gradually from top to bottom. So you see it as an egg or bump, rather than a flat, shaded disk; it is the “best-fit” hypothesis. But then the brain says, in effect: “The variation in luminance—light on top—is obviously not from the object itself, but because of the way it is illuminated

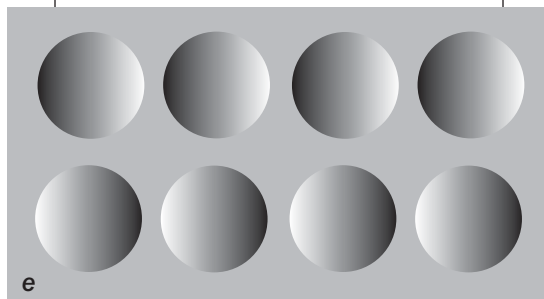
ment apply to the light-on-side eggs seen in *e*, especially given that the luminance gradient is exactly the same? It is because the brain is not used to side-ways illumination. Consequently, the impression of depth is weaker, and the correction for luminance variation (lightness constancy) is correspondingly weaker. The gradients of perceived lightness therefore appear steeper than for the top-lit eggs in *d*. The same reasoning applies to the cavities. Because of the phenomenon of inter-reflection (light bouncing off the walls of the interior of a true cavity, partially nulling the gradient produced by illumination), the brain “expects” a smaller illumination gradient in cavities than in eggs. So it only weakly applies the constancy correction to the former. This milder correction would be sufficient in the real world, but the shading of the artificial cavities in *d* is physically identical (though inverted) to that of the eggs. Thus, the perceived gradient of lightness is higher than it is for the eggs. A second reason is that cavities are less common than bumps, and therefore the visual system is less adept at this constancy correction.

We have presented these complex arguments to emphasize that even extraordinarily subtle aspects of the statistics of the world are built into the visual system as rules. We can devise extremely simple displays from which we can use clues—like Sherlock Holmes—to help solve the mystery of visual perception. **M**

VILAYANUR S. RAMACHANDRAN and DIANE ROGERS-RAMACHANDRAN are at the Center for Brain and Cognition at the University of California, San Diego.

lightful size constancy explanation for the Mueller-Lyer illusion. He points out that the contours of this illusion are identical to the contours one encounters when viewing the outside edge of a building or inside corners of a room (*c*, on preceding page). In this two-dimensional projection of a three-dimensional world, the inside corner of the room is seen as farther away; size scaling is triggered and produces the misperception of different line lengths. As with the Ponzo illusion, whereas depth is implied by this figure, it need not be consciously experienced. The perspective lines, Gregory proposes, directly set constancy scaling, so judgments of distance are unnecessary.

Let us now return to the eggs and cavities. We have explained the illusion of depth as being based on a built-in assumption that the light is shining



from above, so I will see it as uniform in reflectance.” This effect of lightness constancy implies that if you did not see depth in the display there would be no lightness constancy and you would in fact see the top as being much lighter and the bottom much darker than they seem now.

Now why does not the same argu-

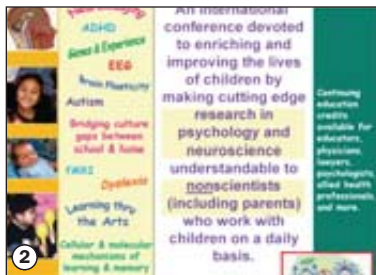
(Further Reading)

- ◆ **Eye and Brain: The Psychology of Seeing.** Richard L. Gregory. Princeton University Press, 1997.
- ◆ **Seeing Black and White.** Alan Gilchrist. Oxford University Press, 2006.

(calendar)



1



2



3



4

"WTC 11.11.03." BY GERARD MAYNARD Brooklyn Museum, promised gift of Peter and Eileen Broido (1); COURTESY OF "BRAIN DEVELOPMENT AND LEARNING: MAKING SENSE OF THE SCIENCE" (2); ETIENNE GEORGE Warner Independent Pictures (3); HTTP://EN.WIKIPEDIA.ORG/WIKI/Portal:Mind_and_Brain (4)

MUSEUMS/EXHIBITIONS

1 Looking Back from Ground Zero: Images from the Brooklyn Museum Collection

The fifth anniversary of the September 11 attack is upon us. The focus of this exhibition of works in various media is the transformation of the landscape of lower Manhattan and Ground Zero leading up to, during and after that appalling crime; it is a change that serves as a physical metaphor for the paradigm shift in our individual and national psyches.
Brooklyn Museum, New York City
 August 31–December 17
 718-638-5000
www.brooklynmuseum.org

Robots and Us

A gizmophile's exhibition that highlights "the curious intersection where people meet machines." The troupe of robots for work and play includes a face-recognition device; museumgoers are challenged to don disguises in an attempt to fool it. Also, care to have a Turing test with your tea? This exhibition, originally put together by the Science Museum of Minnesota, is slowly traveling around the country.
Museum of Science, Boston
 September 30–January 1, 2007
 617-589-0250
www.mos.org

CONFERENCE

2 Brain Development and Learning: Making Sense of the Science

A conference for physicians, educators and parents. It covers the latest developments in child and adolescent neuroscience and development and is organized by a psychiatrist and a psychologist from the University of British Columbia. The two themes for this year's meeting are "Brain Plasticity" and "Interventions."
 August 19–22
 Vancouver, B.C.
 e-mail: devcogneuro@gmail.com
www.interprofessional.ubc.ca/brain_dev_and_learning.html

MOVIES

How to Eat Fried Worms

There are more ways than one to deal with bullies in the classroom, some of them less palatable than others. Billy (Luke Benwald) accepts a dare on his first day at a new school; if he wins, it might make his life easier—if only he can get through the menu items. The film is taken from the popular Thomas Rockwell book of the same gastronomic persuasion.
New Line Cinema
 Opens August 25
www.friedwormsmovie.com

Idiocracy

A top-secret government program needs a guinea pig. Shuffling up to the plate is a naive American soldier (Luke Wilson) who gets himself sent 1,000 years into a future where the people are so dumbed down and hapless that he's the smartest guy in any room. Director Mike Judge's 1999 film *Office Space* was a hilarious satire on the cubicle farming of American business; this film takes on the much wider target of an entire social system.
20th Century Fox
 Opens September 1
www.foxmovies.com

Snakes on a Plane

Samuel L. Jackson, helped by various good guys, battles assassins and, of course, deadly reptiles. I'm looking forward to this one as I have neither a snake phobia nor a fear of flying, but if the sequel is called *Tarantulas in a Confined Space*, I'll pass.
New Line Cinema
 Scheduled to open August 18
www.snakesonaplane.com

3 The Science of Sleep

From the director of *Eternal Sunshine of the Spotless Mind* comes another journey along the "what if" paths traversing the landscape of the human mind. Director Michel Gondry takes Stéphane (Gael García Bernal) on a mad romp between the

reality of his dreary (but comic, at least to us) life and the visually stunning contents of his sleeping head. Unfortunately for Stéphane, his dream and waking worlds begin to blend together, and as he struggles with his inner turmoil he wins and loses the romantic interest of his neighbor (Charlotte Gainsbourg). The narrative arc in this film may be twisted, but the images are mind-bending.

Distributed in the U.S. by Warner Independent Pictures
 Opens starting August 4
www.gaumont.com/films/sleep/index.html

WEB SITES

<http://neuropsychological.blogspot.com/>
 "BrainBlog." News and commentary from current research in neuroscience, well written by a consulting neuropsychologist.

<http://intelligencetesting.blogspot.com/>
 "Intelligent Insights on Intelligence Theories and Tests (aka IQ's Corner)." Kevin McGrew, a professional in the psychometric field, also offers an excellent set of links (mostly to blogs in related fields), which save you the trouble of staying up all night trolling the Internet to get the "blox populi" of the mind and brain community.

4 [http://en.wikipedia.org/wiki/Portal: Mind_and_Brain](http://en.wikipedia.org/wiki/Portal:Mind_and_Brain)

Here is the Mind and Brain Portal from Wikipedia, that vast agglomeration of information freely available (and freely flung together, sometimes unevenly) on the Web. The portal provides a handy interdisciplinary point of entry to a good deal of information in such related fields as the philosophy of mind, neuroscience, linguistics and psychology, listed as topics in categories such as News and People; there's always an interesting Showcase Article.

Compiled by Dan Schlenoff.
 Send items to editors@sciammind.com

The Teen Brain,



Hard at Work

No, really

By Leslie Sabbagh

It is late in the evening rush hour, typical stop-and-go traffic. Finally, there is a break; the tightly packed group around you is soon cruising together at 55 mph. Suddenly, you see brake lights flare up ahead. As you prepare to brake, you glance in the rearview mirror and see an alarming sight—a car closing way too fast on your rear fender. The teenage driver looks panicked, one hand clutching the steering wheel, the other hand clenching a cell phone. You brace for the terrible impact ...

We are quick to blame adolescents for getting themselves into predicaments that adults believe could be easily avoided. But recent research indicates that simple irresponsibility may not be the full explanation. When teenagers perform certain tasks, their prefrontal cortex, which handles decision making, is working much harder than the same region in adults facing the same

In stressful conditions, such as a sudden traffic jam, a teen's prefrontal cortex may become overloaded, causing slow or bad decisions—an accident waiting to happen.

circumstances. The teen brain also makes less use of other regions that could help out. Under challenging conditions, adolescents may assess and react less efficiently than adults.

Understanding the capabilities and limitations of the brain at different developmental stages is crucial for education and psychological assessment. Ironically, although the teenage years are widely recognized as a period of tremendous growth and change, the mental capabilities of teens have been less studied than those of children or adults. As more work is completed, it is becoming apparent that society should not be

fooled into thinking that a teen has the mental prowess of an adult just because he or she looks and, most of the time, behaves like one. Brain processes that support cognitive control of behavior are not yet mature. Add stressors to the mix—like a sudden highway jam—and a teen can be an accident waiting to happen.

Self-Control Difficulties

As recent studies underscore, differences in the prefrontal cortex—responsible for the so-called executive function that underlies planning and voluntary behavior—may be one of the most important distinctions between adolescents and adults. Beatriz Luna, director of the Laboratory of Neurocognitive Development at the University of Pittsburgh, has pinpointed differences by scanning the brains of teens and adults with functional magnetic resonance imaging (fMRI) during demanding tests of the visual-motor system.

In one setup, subjects faced a computer that flashed lights randomly. They were told either to rapidly focus on the lights or to try to avoid looking at them. Luna found that “teens used more of their prefrontal cortex resources than adults did.” Indeed, the amount of prefrontal cortex employed was similar to what adult brains use when performing a much more complex task. This excessive reliance, Luna says, “can lead to error, especially when difficulty increases.”

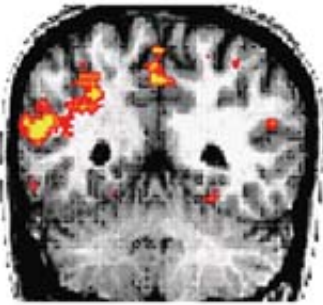
Psychologists distinguish between two types of behavior control: exogenous and endogenous. Exogenous control is reflexive, generated in response to external stimuli—for example, focusing on lights as they appear on the screen. Endogenous control is voluntary and generated by an internal plan—trying not to look at the lights. A mature prefrontal cortex makes it easier for endogenous behavior to override exogenous behavior. In the traffic scenario, the exogenous response of the teen who suddenly realizes he is going to hit your rear bumper would be to freeze and scream, whereas the endogenous response would be to brake hard and steer out of the way. But for teen brains, deliberately overriding the exogenous reaction is more difficult than it is for adult brains.

Experts such as Luna maintain that although adolescents can at times demonstrate adult-level cognitive control of decision making, this endogenous power is only beginning to mature. In the visual-motor tests, she explains, subjects must use the prefrontal cortex to tell the rest of the brain how to behave. “Adolescents show similar capabilities of inhibition compared with adults,

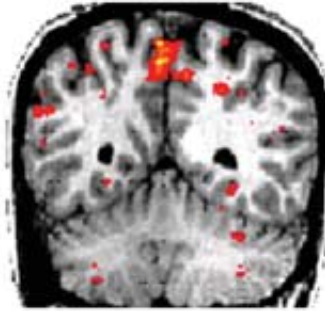


Bad decisions and risky behavior may result from an immature prefrontal cortex, not just rebellion.

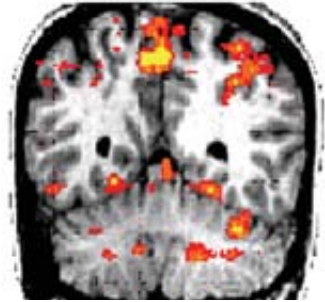
Children
Ages 8 to 13



Adolescents
14 to 17



Adults
18 to 30



but the fMRIs show that they are using up prefrontal cortex like crazy,” Luna notes. Adults call on other parts of the brain “to collaborate and better distribute the workload,” she adds.

The implication is that if something unexpected occurs in an already stressful situation, an adolescent may exhaust his or her prefrontal cortex resources. Adults can better handle the stress by tapping other brain regions. And in everyday life, general overtaxing of the prefrontal cortex may undermine executive function, impairing planned behaviors and choices. That may explain why adolescents exhibit impulsive or thoughtless behavior. For example, Luna says, it is easier for adults to suppress bad responses to peer pressure. They are better able to keep themselves in line, rather than succumbing to temptation.

Overloading the Cortex

Full maturation of executive function occurs only as a completely integrated, collaborative brain system emerges, in the late teens and even in the early 20s, according to psychologists. But in adolescents, a key contributor that helps to guide voluntary behavior—working memory—is also still developing. Luna’s fMRI images support the conclusion that adolescents are not as efficient in recruiting areas that support working memory.

Weak integration has also been found by Susan F. Tapert, associate professor of psychiatry at the University of California, San Diego, who investigated spatial working memory in earlier and later adolescence. Tapert tested 25 young teens (ages 12 to 14) and 24 older teens (ages 15 to 17) using fMRI. Older adolescents, she says, “showed

a little more refined, smaller loci of activation as they performed tasks and used more inferior parietal cortex than younger adolescents.”

Tapert thinks that older adolescents recruit fewer neurons and employ different strategies to perform the same job. Older teens used regions that suggested they solved the task through a verbal strategy, rather than by rote spatial rehearsal. Over the course of adolescence, the brain involves more areas in general and distributes certain tasks to specialized regions, thereby reducing the neuronal effort necessary to achieve the same level of performance. “I was surprised with the magnitude of change we observed across this relatively narrow age range,” Tapert says.

Early adolescents can perform well on spatial working-memory tests, but it appears they need to engage in more neural activity. They also become much less efficient if they are stressed when asked to perform an additional task. Only at the end of adolescence, Tapert says, is spatial working memory efficiently distributed across brain regions.

Still Pruning

Recent structural MRI images of adolescent brains lend credence to the notion that regions of the teen brain involved in decision making and behavior control undergo significant physical changes. Jay N. Giedd, a psychiatrist and inves-

In a test of visual control, adolescents (*center*) called on more brain regions than children, yet far fewer than adults, who better distributed the workload.

(The Author)

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REPRINTED FROM “MATURATION OF WIDELY DISTRIBUTED BRAIN FUNCTION SUBSERVES COGNITIVE DEVELOPMENT,” BY BEATRIZ LUNA ET AL., IN *NEUROIMAGE*, VOL. 13, NO. 5, PAGES 786–793, MAY 2001. WITH PERMISSION FROM ELSEVIER

tigator in the Child Psychiatry Branch at the National Institute of Mental Health, has shown that the dorsolateral prefrontal cortex, important in controlling impulses, undergoes synaptic pruning—the elimination of unnecessary connections between neurons. This results in more efficient transmission of nerve impulses.

Most researchers agree that pruning is a fundamental mechanism for brain maturation. So is

University of California, San Diego, and founder of the Cambridge Center for Behavioral Studies, says he is “infuriated” by the very concept that there is a teen brain that is so different from an adult brain. “There is no such thing. It’s a hoax, pushed to some extent by drug companies who are funding research,” he asserts.

To bust the myth that routine brain development underlies teenage behavioral problems, Ep-

Critics say there is no such thing as a teen brain; the notion is a hoax, encouraged by drug companies.

adding more myelin—insulation around the axons that send signals from neuron to neuron. Both changes translate into improved brain function. Synaptic pruning increases efficiency of local computations, whereas myelination speeds up neuronal transmissions. As a result, Luna notes, the prefrontal cortex is more able to impose voluntary and planned behaviors.

Giedd evaluates data from ongoing MRI studies conducted at the Child Psychiatry Branch. A recent study draws from a pool consisting of 307 children and adolescents who underwent MRI scans and neuropsychological testing. Many have been retested every two years. Giedd says the initial surprise is that “the brain doesn’t change that much in size from age six on.” The skull thickens, but the brain is at 90 percent adult size. Its overall breadth is stable during the teen years, “but the components change in size and shape,” he adds.

The MRI images show alterations in the wiring among neurons involved in decision making, judgment and impulse control, as well as in the wiring the prefrontal cortex uses to tie brain regions together. Along with other studies, the images show that the prefrontal cortex seems to continue maturing well into the 20s. “It is striking how dynamically the brain changes during the teen years and how long it changes into young adulthood,” Giedd says. “Frankly, it surprised us that [ongoing change] lasted so long.” Whereas much change occurs during the teen years, adaptation in the prefrontal cortex continues for a number of years.

A Hoax?

Not all neuroscientists or psychologists are ready to accept that the teen brain’s innate biology explains reckless behavior, however. Robert Epstein, a psychologist, visiting scholar at the

stein cites the influential book *Blaming the Brain*, by Elliot Valenstein (Free Press, 1998), now psychology professor emeritus at the University of Michigan at Ann Arbor. It implies that some neuroscientists come under the influence of drug companies that want to develop the idea that the brain is at fault, easing the way for doctors to prescribe psychoactive drugs. (Note that none of the studies discussed in this article were funded by drug companies.)

Perhaps more persuasive is Epstein’s observation that studies that implicate a teen brain tend to look only at American adolescents. He says research shows that “teens in other countries and developing nations don’t behave or feel like American teens. If you look at multicultural and causation issues, there is no teen brain” that is universally different from adult brains.

American culture has come to define teenage years as tumultuous. “But most teens around the world don’t experience any such turmoil,” Epstein notes, citing a massive study by anthropologists Alice Schlegel of the University of Arizona and Herbert Barry of the University of Pittsburgh. Their book *Adolescence: An Anthropological Inquiry* (Free Press, 1991) examined teens in 186 preindustrial cultures. Schlegel and Barry found that 60 percent of the cultures do not even have a word for adolescence and that most teens spend much of their time with adults, not segregated with only their peers. Antisocial behavior was absent in over half the cultures; where it was found, it was mild.

This is “mind-boggling,” Epstein declares, because in America “we define the teen years as storm and stress. To point to the brain as the cause of everything bad is wrong, because environment changes the brain. We live in a society where kids are isolated from adults, so they learn



from each other.” And that, he says, can be a recipe for trouble. Epstein contends that when a society raises adolescents to experience a smooth, swift transition to adulthood, much of the angst assumed to be a given with teens is absent.

Ready or Not

Luna calls Epstein’s view “interesting,” although she does not agree. Either way, she says, her experiments control for cultural differences because they look at brain function based on emotionally neutral stimuli, not socially relevant behavioral decisions.

As for environmental influence, Luna says the fMRI images confirm that the brain is a vulnerable system and that in an environment with many stresses it is more difficult for adolescents to show self-control as compared with adults. She points out that the structure of the teen brain is “not ready” and that this is a good thing, because it allows the brain to develop more consistently with the particular environment in which it matures. “We’re trying to understand the brain-behavior relationship,” she adds. “It’s not like the teen brain is different from other brains. There is a continuum.”

The visual-motor test, she observes, is very difficult, “because the whole brain is wired to look at a visual stimulus.” Asking subjects to not look at

the light requires frontal regions to communicate with subcortical regions to enforce a planned, endogenous response (“I will not look at the light”) that overrules the reflexive, exogenous response (“Look at the light”). “We’re asking a teen to do something” that, at most, is only remotely related to risk-taking behavior, she says. “It is a way to look at the basic ability to inhibit a response.” Because adolescents have a much harder time performing tasks that require voluntary control, they could be more prone to bad decision making.

Yet when adolescents are in situations with few competing demands, they do indeed behave like adults, Luna says. In preindustrial cultures that is the more likely environment, “so, of course, those teens might not exhibit risk-taking behavior. That doesn’t mean their brain is not pruning,” she explains. “Or that there isn’t something uniquely special about adolescence.” **M**

Adolescents in certain cultures are not racked with the turmoil of American teens, indicating that environment, not inherent brain development, may underlie troubled behavior.

(Further Reading)

- ◆ **Adolescent Brain Development: Vulnerabilities and Opportunities.** Edited by Ronald E. Dahl and Linda Patia Spear. *Annals of the New York Academy of Sciences*, Vol. 1021; June 2004.
- ◆ **fMRI Reveals Alteration of Spatial Working Memory Networks across Adolescence.** A. D. Schweinsburg, B. J. Nagel and S. F. Tapert in *Journal of the International Neuropsychological Society*, Vol. 11, pages 631–644; 2005.
- ◆ **Intellectual Ability and Cortical Development in Children and Adolescents.** P. Shaw et al. in *Nature*, Vol. 440, pages 676–679; March 30, 2006.

Turning Off Depression



Helen Mayberg may have found the switch that lifts depression—and shined a light on the real link between thought and emotion By David Dobbs

Given her background and curiosity, Helen Mayberg seems to have been destined from girlhood to do what she is doing now—even though her current work was inconceivable then. Her father practiced family medicine in Los Angeles County. Her uncle used x-rays and nuclear medicine machines to research biochemistry. Today Mayberg peers into brains to examine mood networks—and with one startling experiment has transformed the treatment of depression. At the same time, by combining her father's bedside dedication with her uncle's technical sophistication, she is changing the leading theories of how thought and mood interact.

Like many researchers, Mayberg began her career hoping to advance her discipline. She expected to do so in the usual way, by slowly accruing results that would eventually alter the landscape. Now based in Atlanta at Emory University as a professor of psychiatry and neurology, she has indeed achieved such an effect. But last year she also created a big peak all at once, when she and two collaborators described how they cured eight of 12 spectacularly depressed people—individuals virtually catatonic with depression despite years of talk therapy, drugs, even shock therapy. They did so by inserting pacemakerlike electrodes into a spot deep in the cortex known as area 25. A decade earlier Mayberg had identified area 25 as a key conduit of neural traffic between the “thinking” frontal cortex and the central limbic region that gives rise to emotion, which appeared earlier in our evolutionary development. She subsequently found that

area 25 runs hot in depressed and sad people—“like a gate left open,” as she puts it—allowing negative emotions to overwhelm thinking and mood. Inserting the electrodes closed this gate and rapidly alleviated the depression of two thirds of the trial's patients.

The study won her instant renown. “Mayberg is beginning to do for depression what we did 25 years ago for cancer,” says Thomas Insel, director of the National Institute of Mental Health. “It's early yet. But we can safely say that Mayberg's work shows us whole new avenues into understanding and treating depression.”

Mayberg's success stems from a certain irony. She thinks she is probably the only board-certified neurologist whose main title is professor of psychiatry, which she says is “sort of strange” considering that she rejected psychiatry, her original choice of study, as too nebulous a discipline. “I didn't like the tool kit,” she explains. Even though she says she is “all about the wiring diagram” of the brain, she has produced one of the most significant findings in years about depression, psychiatry's most common and elusive patient problem. And her discovery could redefine our understanding of the relation between reasoned thought and unreasoned emotion.

The Grail: Area 25

Sit down for dinner with Mayberg, as I did at Mayhene's in Washington, D.C., where she had come for a conference, and you are treated not just to a good meal but to intellec-

ERIK S. LESSER



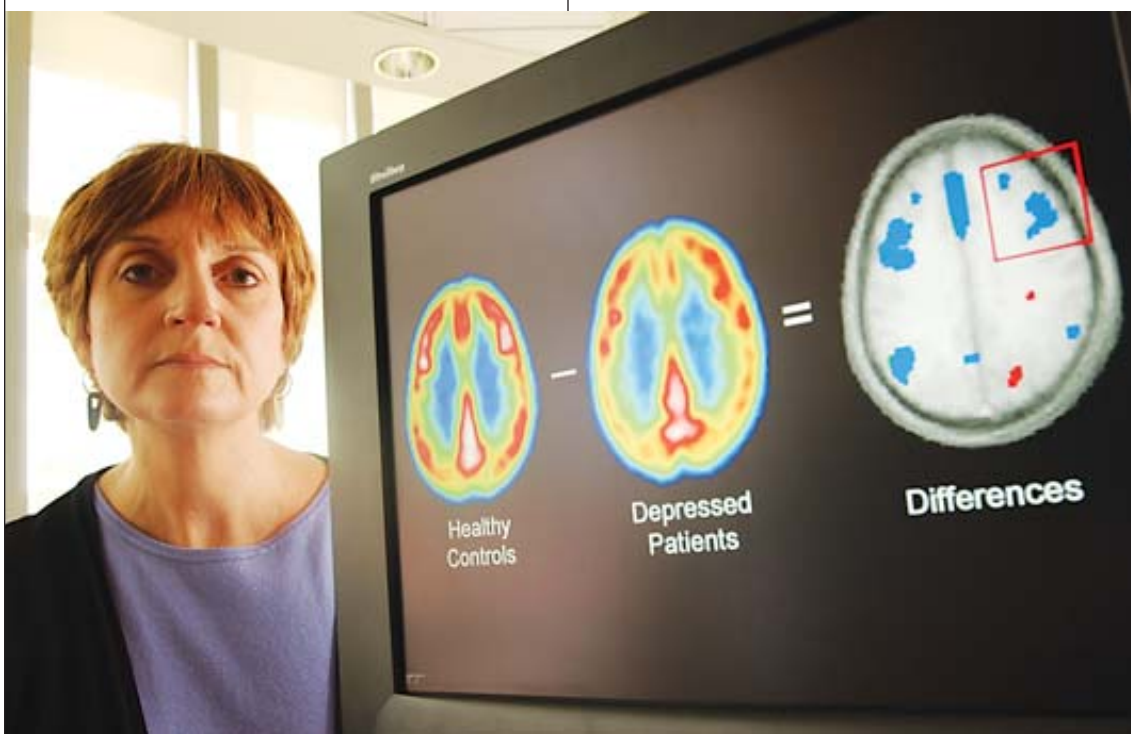
CSA PLASTOCK Getty Images

tual excitement. Lively, with big eyes and a ready smile, Mayberg exudes the enthusiasm of a freshly inspired grad student combined with a 50-year-old veteran's appreciation of history.

"I was always a tinkerer," she recounts. "Summers I used to spend hours in my uncle's lab [at the University of California] at Berkeley. He did early work mapping out thyroxine dynamics in the brain. We'd talk mapping, which I've always found fascinating, and he'd give me little lab tasks to do. I loved the lab—the logic of it, the gadgets and Geiger counters. Measuring things to solve puzzles."

single unit. Dysfunction results from breakdowns in the coordination between regions.

Geschwind's vision, buttressed by his research and brilliant readings of earlier cases from neurological literature, led the profession's move from the view of a monolithic brain, which dominated the first half of the 20th century. When Mayberg began studying with Geschwind, the emerging network model was being confirmed by an explosion of discoveries about how hormones and neurotransmitters carry messages between various brain areas. Mayberg, watching Geschwind apply these models to patients on Beth Israel's neuro-



Equation solved:
By comparing brain images of people with Parkinson's, Huntington's, epilepsy and stroke, Mayberg discovered the provoker of clinical depression.

She entered medical school at the University of California, Los Angeles, figuring she would be a psychiatrist. Yet when she advanced to her psychiatry rotations in the late 1970s she found few gadgets and little quantitative measurement. "There were no CT scans available then," she recalls, "much less PET imaging or fMRIs. And most psychiatrists didn't fully accept the biology underlying psychiatric disorders." For instance, the profession viewed schizophrenia—which today is seen to rise from genetic and neural underpinnings—as primarily a reaction to maternal neglect or abuse.

In 1980 Mayberg did a senior-year clerkship with neurologist Norman Geschwind at Harvard University's Beth Israel Hospital. Geschwind had spent four decades pushing the notion that the brain works as a system of coordinated functions that arise from different regions, rather than as a

ogy wards, found a far more appealing theory of mental function than psychiatry offered.

After graduating, she took up a neurology residency at Columbia University, where she investigated depression in stroke patients. She hoped to localize the neural networks involved. But the stroke patients' lesions varied so much in location and severity that she could not find consistent patterns.

Still, the project honed her interest, and when she finished the residency and moved to a postdoctoral program at Johns Hopkins University, she began studying depression in Parkinson's patients. Parkinson's offered more promise for isolating neural networks, because it results from damage to a well-defined, deep-brain structure crucial to movement, the globus pallidus. At the time, Johns Hopkins led the world in neurotransmitter re-

ERIK S. LESSER

search, breaking new ground almost monthly on dopamine and serotonin function, so Mayberg naturally started by trying to find anomalies in the patients' neurochemistry. But focusing on chemicals suited her little better than psychiatry did.

"With psychiatry," she explains, "the resolution was the whole brain. That was too low resolution for me. I discovered that the chemistry"—neurotransmitter action at the cellular level—"was too fine a resolution. I wanted to see how the parts worked together."

So Mayberg, applying her uncle's discipline of nuclear medicine, developed a new project in the early 1990s. She and some collaborators scanned 60 Parkinson's patients, some depressed and some not, with positron-emission tomography (PET). They were looking for differences in activity in

perhaps it actually caused the problem by kicking into overdrive and letting depressive loops take over. In any case, Mayberg says, "we were seeing area 25 as important." It suggested a pattern, something fundamental about depression.

In 1997 Mayberg wrote a long theoretical review paper describing the findings supporting this pattern. Few psychiatrists took notice. "Quite frankly," she says, "no one was particularly interested. I was asking them to look at a lot of brain regions and think of depression in a new way. People weren't ready for it. So I got put in a box." Because most of her studies had been on people suffering some other neurological problem, such as Parkinson's or epilepsy, her colleagues branded the patients as having "secondary depression" rather than ordinary "primary depression." Their

“I was saying, ‘No, no, *no!* This is about *all* depression.’ But it just seemed to annoy people.”

the frontal and paralimbic regions—the “thinking” frontal cortex behind the forehead and the “older,” more interior paralimbic cortex surrounding the limbic centers for emotion, memory and learning. They found that the depressed patients showed far less activity in both cortex regions. Over the next few years Mayberg performed similar studies comparing depressed and nondepressed patients who experienced stroke or who had Huntington's, epilepsy or Alzheimer's. The depressed patients in every study had the same reduced frontal and paralimbic activity.

Mayberg also found something else: the depressed people had one particular segment of evolutionarily older cortex, just over the roof of the mouth, that was especially *busy*. It was the region called area 25. Another researcher working independently—Wayne Drevets of Washington University (now at the National Institute of Mental Health)—also noticed this hyperactivity. The notion seemed odd; in depression, characterized by underactivity in the brain, one localized network was overactive. Area 25 proved to have strong connections between the limbic system's emotional and memory centers and the frontal cortex's thinking centers. Exactly how area 25 modulated traffic between these districts was not clear, but the region was clearly hyperactive in cases of severe depression. Perhaps it was working overtime as it tried to temper a depressive loop set up between emotional and thinking centers. Or

symptoms were an inevitable—and essentially unimportant—side effect of the main condition.

“So they'd say, ‘Oh, you do that neurological depression stuff,’” Mayberg recalls. “‘Very nice.’ And I'm saying, ‘No, no, *no!* This is about *all* depression.’ But it just seemed to annoy people.”

Stumped

Annoyance changed to attention at the century's turn, however, as Mayberg tested her assertions with increasingly revealing studies. She asked healthy subjects to think sad thoughts and scanned them when the tears were flowing. The images showed depressed frontal activity and a hyperactive area 25. Yet as the sadness passed, the frontal area revived and area 25 calmed. She scanned depressed patients undergoing treatment with Paxil or with placebos. In both groups, individuals who recovered showed a rise in frontal activity and a calming in area 25. It seemed that, no matter what the cause, depression dampened frontal activity and either caused or rose from hyperactivity in area 25. And for all afflicted, curing the depression reversed these effects.

Then, in early 2004, Mayberg published a

(The Author)

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study that drew wide notice, and her own results threw her for a loop. She scanned two groups of depressed patients undergoing treatment—one with Paxil and the other with cognitive behavioral therapy (CBT), which aims to cure through counseling. The Paxil patients showed the same pattern as the earlier studies had found. The CBT patients displayed a new and confounding dynamic, however: when CBT treatment worked,

ers had discovered about the dynamics of fear, anxiety, stress and mood. Researchers such as New York University neuroscientist Joseph E. LeDoux [see “Mastery of Emotion,” by David Dobbs; SCIENTIFIC AMERICAN MIND, February/March] and Bruce McEwen, a neuroendocrinologist at the Rockefeller University, had shown that mood disorders often develop because extreme or continuous stress, whether from a trauma or a

(As soon as the electrodes were turned on, patients saw better, **thought better**, felt better.)

area 25 slowed down, as expected, but the frontal areas showed *less* activity. They went from heightened to lower activity, instead of low to high, as had occurred in every other group.

“Oh, *man*,” Mayberg says. “I was stumped. For a while I had to just set it aside.” Why did the CBT patients’ frontal activity drop instead of rising as they got better? After discussions and contemplation, she finally realized the answer. The successful CBT patients, almost by definition, had to show this pattern. In CBT, patients learn to recognize and change thought patterns that would otherwise depress them. An active frontal area was virtually required to make CBT work. The patients who responded to CBT did so either because they were busier thinkers by nature (and therefore more amenable to CBT) or because they entered the study already trying to think their way out of their depression. The scans showing initial high levels of frontal activity, Mayberg explains, “were pictures of the tug-of-war between the depression and the patients’ attempts to self-correct.” When the attempt succeeded, the frontal areas could relax, and the scans showed the reduced activity.

This anomalous result held ripe suggestions about what kind of patients might best respond to CBT versus drug therapy. It also highlighted the central finding uniting all the various studies: even the CBT responders had an initially hyperactive area 25 that settled down as therapy worked and mood improved. Area 25 was overly busy in all types of depressions and was calmed by any successful therapy.

Instant Relief

Mayberg now possessed strong, replicated evidence that area 25 played a fundamental role in depression. This insight fit well with what oth-

er difficult ongoing environment, kick fear and anxiety centers into long-term overdrive. The survival systems that have long served us well—a heightened neural and hormonal response to acute threat—turn corrosive when such memories and persistent thoughts trigger them continuously. The evidence for this dynamic was robust. But the crucial switches in the circuit remained elusive. Maybe, Mayberg started to think, area 25 was such a switch, and tweaking it could trip the circuit out of alarm mode and back to normal.

At about this time, Mayberg took a professorship at the University of Toronto, where she met fellow faculty members Sidney Kennedy, a psychiatrist, and Andres Lozano, a neurosurgeon. Kennedy liked to explore neurological models of depression, and Lozano had gained notoriety modulating another neural network gone awry—the one responsible for Parkinson’s. In the 1980s it became common for surgeons to treat severe Parkinson’s by removing the globus pallidus. The cluster of neurons is a gateway in circuits that control movement, and its hyperactivity somehow threw the neurology of movement off balance, causing the tremors and rigidity that afflict Parkinson’s patients. Removing the globus pallidus seemed to reduce these complications. Lozano, on the other hand, had become one of several neurosurgeons who treated the same problem not by removing the globus pallidus but by inserting next to it a tiny, low-voltage electrode. The technique, called deep-brain stimulation, seemed to regulate the activity of the globus pallidus, restoring movement to near normal.

Might inserting such electrodes alongside area 25 calm it down? Mayberg, Lozano and Kennedy decided to try it. Beginning in 2003, the team implanted electrodes in area 25 in a dozen severely

depressed patients. Lozano drilled a pair of nickel-size holes in the top of the skull, slid a pair of electrodes and slender leads to area 25, attached the leads to a small pacemaker sewn in under the collarbone, and turned it on. The pacemaker sent a continuous four-volt current to area 25.

The results were stunning. Some patients felt profound relief as soon as Lozano turned on the electrodes, and two thirds returned to essentially normal mood and function within months. They saw better, thought better, felt better. They talked of feeling like they were walking amid flowers, of “the noise” stopping, of a horrid weight lifting. Side effects were almost negligible.

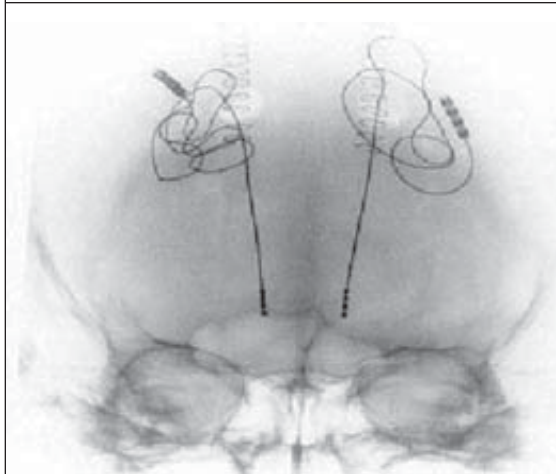
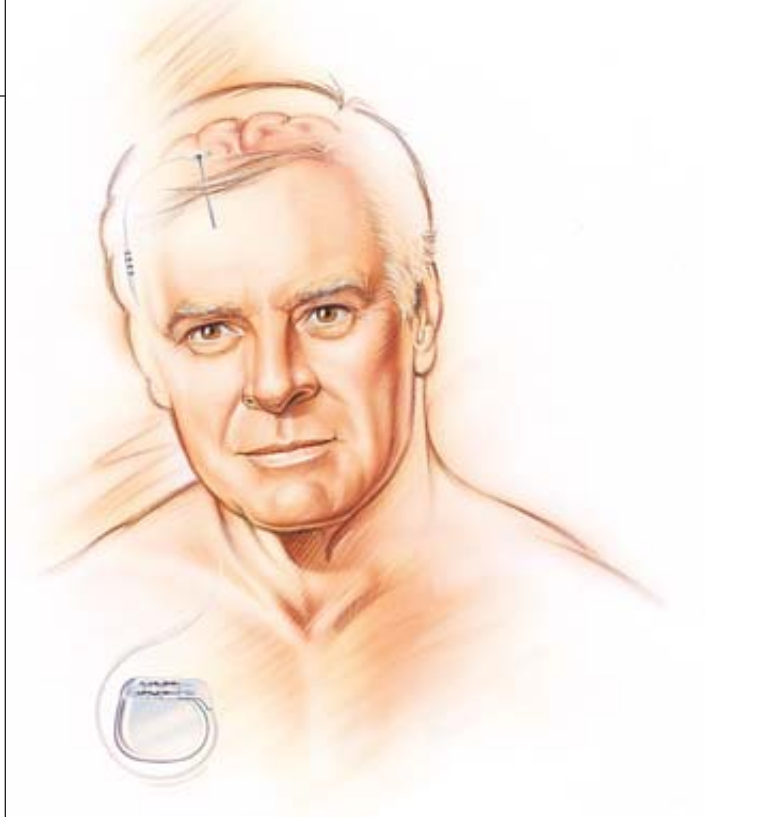
“We still don’t really understand why calming area 25 has such an effect,” Mayberg says. “That comes next. But it’s clear that it causes depression when it’s hyperactive and that calming it can bring relief.” Indeed, the results shattered doubts. Mayberg’s body of work, and this latest experiment in particular, had shown that in the emerging circuit model of mood, one could identify and modulate key switches. The results emphatically confirmed the network model of the brain as well as a long history of thought and metaphor. Reason and passion, thought and emotion, were indeed linked in a loop rather than stacked in a hierarchy. Neither stood as the other’s slave. They engaged in a conversation that, to be healthy, had to be rich and balanced.

Figuring Out Why

The deep-brain-stimulation trial brought Mayberg fame. The renown she doesn’t mind; the affirmation she likes. “It’s nice,” she says, “after years of writing papers people didn’t finish reading, to have people pay attention. And as a scientist, this is what you really hope for: to feel like you’ve gripped the wheel of a really big ship and changed its direction, even a little bit.”

Yet Mayberg hardly thinks she has solved the big questions of mood and mental health. She hopes to find new tools and new working models to track and treat the complex network that links thought and mood—the cortex and limbic regions—and sends us spiraling into depression when it malfunctions. Most immediately, this search means detailing how area 25 plays so crucial a role.

“I may spend the next 10 years trying to figure out what we did,” she muses. “We really did this mostly by eye. I want to figure out how to better work this area. I’d like to better define the neural network—the actual wiring, if you will. I’d like to map the neurochemistry more finely. I



Relief: An implanted pacemaker (top) sends current to two electrodes that reach deep into the brain, stimulating area 25 (bottom, at center) to close the open gate that feeds depression.

want the genetic layout. What will all that tell us about the nature of depression? Can we find more reliable differences among different types of depression? Why do some people respond to drugs and some to CBT?”

Many people would flinch at so many questions. Helen Mayberg lights up. “You know what cracks me up?” she remarks. “When people ask, ‘So where are you going to look next?’ I tell them, ‘What do you mean, where am I going to look next? I’m going to look more closely here.’” **M**

(Further Reading)

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Diversity at Work

**“Diversity” in
employee teams
does not always
equal superior
performance**

By Elizabeth Mannix and
Margaret A. Neale

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Gender diversity did not appear to sway group performance one way or the other in one study.

Diversity is good, goes the conventional wisdom of the business world: companies that look and think more like the spectrum of their customers serve their clientele better. With a greater number of perspectives brought to a problem, diversity opens up new opportunities for synergistic information sharing, lifting a team's creativity and work quality, proponents say. Successes such as inventing cosmetics for women with various skin tones, employing Spanish-speaking sales representatives, and marketing vacations to locations of historical importance to African-Americans readily come to mind.

Yet the diversity picture is not all rosy, reveals our analysis of 50 years of research. *How* a company chooses to diversify is a critical yet overlooked aspect of *why* it does so. Diversity can be a powerful tool—but it is one that can cut both ways. Without proper management or worker training, diversity can actually dampen group performance. And the very ways that managers typically judge differences when they are staffing teams—in particular, surface attributes such as ethnicity, gender and age—may be more likely to have negative effects on the ability of these groups to collaborate.

Why hasn't the reality of diversity always



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matched up with the ideal? In many cases, it is because corporations have implemented policies and practices that emphasize diversity without a sufficient grasp of the factors that help such individuals come together in effective teams. Lacking a proper understanding of the complex social-psychological mechanisms, managers risk leaving their employees prone to disruptive divisions. Nevertheless, the research offers encouraging news, too: although leading or working with a set of dissimilar people can be difficult, remedies for managing, and capitalizing on, that diversity exist.

A Changing Workplace

We define diversity as “any personal attribute that someone else may use to detect individual differences.” We realize the scope of that description is broad; thus, it may be useful to review the categorization schemes that social scientists have developed to explore the effects of diversity in teams.

In general, scholars have relied on two paradigms to define and understand diversity. The first is an approach based on factors, in which types of diversity are identified and measured.

plines and functions more critical than ever.

Half a century of research on diversity, however, reveals that its overall benefits are not clear-cut. Indeed, the business case (in terms of demonstrable financial results) for diversity remains hard to support, as reported a recent study by Thomas A. Kochan of the Massachusetts Institute of Technology and researchers from institutions that included the Harvard Business School, the Wharton School at the University of Pennsylvania and Rutgers University.

First, the type of diversity may affect the group. Though the findings are not uniform in every study, differences based on surface-level, or superficial, social categories—such as race, ethnicity, gender and age—are more likely to affect group performance, commitment and satisfaction negatively; one possible explanation is that such differences trigger preconceived stereotypes and biases. In their five-year study, for instance, and consistent with most of the research on this topic, Kochan and his colleagues found that racial diversity tends to hurt team processes. In contrast, underlying differences, such as functional background, education or personality, tend to improve collective performance—but

(Firms have emphasized diversity without a sufficient grasp of how individuals work as a team.)

Factor approaches tend to fall into two categories themselves: bi-factor approaches, in which diversity is coded into two major types (such as visible and nonvisible), and multifactor, in which attempts are made to create exhaustive categories (such as demographic, education, values and personality factors). The second paradigm is an approach based on proportions, or ratios, of minority to majority members. This more generic approach tends to treat the types of diversity as interchangeable and focuses on proportion size (token members versus more balanced groups) as the variable of interest.

By any measure, the North American workplace has become increasingly diverse in recent decades. Changing population demographics and the welcome advancement of women and racial and ethnic minorities have literally changed the face of corporations. At the same time, many businesses have flattened organizational structures, using work groups to get tasks done—and making effective collaboration across disci-

only when the group process was managed appropriately. (More on that later.)

In a field study of 92 work groups published in 1999, researchers Karen A. Jehn of Leiden University in the Netherlands, Gregory B. Northcraft of the University of Illinois and one of us (Neale) distinguished among three types of diversity: social category, informational and values. Social-category diversity, as measured by heterogeneity in sex and age, positively influenced group-member morale. Informational diversity, or differences in education and functional area (or role) in the firm, increased task conflict (that is, conflict over ideas, opinions or ways of approaching the group task), which enhanced group performance. And finally, value diversity, as measured by perceptions of differences in goals and values among group members, decreased individual satisfaction and commitment to the group.

Another study, also published in 1999, found complex links between diversity, conflict and work-group performance, depending on whether

the diversity was relevant to the job. Lisa Hope Pelled and Katherine R. Xin of the University of Southern California and Kathleen M. Eisenhardt of Stanford University defined “job-relatedness” as the extent to which the variable “directly shapes the perspectives and skills related to cognitive tasks.” Functional-background diversity, which is job-relevant, beneficially intensified task conflict; greater task conflict improved cognitive performance. Racial diversity, high in visibility but low in job-relatedness, boosted affective conflict (that is, interpersonal tension and emotion-

1980s and early 1990s. They found that whereas women tend to prefer gender balance or even male dominance at work, men in mixed-gender settings reported experiencing significantly lower job satisfaction and self-esteem and more job-related depression than men in either male- or female-dominated settings.

In 1998 Dora C. Lau of the University of British Columbia and J. Keith Murnighan of Northwestern University suggested a way to reconcile the proportion and factor approaches with their theory of group fault lines. These hypothetical

(Perceptions of competition can make so-called balanced groups particularly dysfunctional.)

based conflict); affective conflict depressed group performance. Age diversity, another highly visible type, lowered affective conflict. Gender diversity did not appear to sway group performance one way or the other. Interestingly, both group longevity and task routineness (that is, more similarity in the day-to-day demands of the job) moderated these effects. In groups that had worked together longer, the association between diversity and conflict was lessened. If the task was routine, the positive association between diversity and emotional conflict dropped. And routineness increased the positive relation between diversity and task conflict.

As we noted, an alternative approach to understanding diversity includes theories that focus on the proportions of minority/majority membership. Some theorists hold that as minority groups grow in proportionate size, majority groups may perceive them as a threat to their own power and claim on scarce resources. Perceptions of competition and power threats lead to rising hostility and discrimination, which explains why so-called balanced groups may be particularly dysfunctional. A 1995 study by Pamela S. Tolbert of Cornell University and others found that university departments with a high proportion of women faculty were significantly less likely to further augment the number of females. These researchers ultimately concluded that “women’s growing representation in a group leads to an increasingly negative environment for them.”

Similarly, Amy S. Wharton, now at Washington State University, and James N. Baron of Stanford looked at the ramifications of gender segregation on men at work in studies in the late

dividing lines may split a group into subgroups, usually based on multiple attributes. According to these theorists, the strength of fault lines depends on three compositional factors: the number of separate attributes apparent to group members, the alignment of sets of individuals as a consequence, and the number of potentially homogeneous subgroups.

Lau and Murnighan have proposed that group fault lines would become more pronounced as more attributes are highly correlated, thus reducing the number and making the subgroups more homogeneous. Think of a group that includes five young white male shipping clerks who have worked for a company for less than a year and five middle-aged black female vice presidents who have been with the company for 20 years or more; the group’s fault line would be particularly strong because all the listed characteristics are highly correlated. In this example, both the type of diversity and the proportions of minority and majority members are important. Little research has been done on this theory, however, and more work is needed to clarify how fault lines may form and affect groups.

Harnessing Diversity

Scholars still have much to learn about the nuanced behavior of diverse people working in groups, but one thing is already clear: unless diverse teams overcome the disruptive effects of their differences or avoid the tendencies to drive out the distinctiveness of minority members, they will be unable to engage in effective and creative problem solving. It is vital for managers to bring a method of social integration to the teams and



their organizations as a whole. The strategy must bridge the chasms formed by diverse characteristics but not eradicate the distinctiveness and uniqueness of individuals and the value that they bring to the team.

We have several suggestions. First, managers should establish clearly the context and purpose of the team and then pick the appropriate members based on that goal. A diverse team with a purely fact-gathering mission might be likely to have very different success than a diverse team with a short-term, goal-directed project. Second, managers must provide ways to bridge the interaction of the diverse team members through connections such as common social ties, values, identity and superordinate (overarching) goals; organizational culture and training are also important. Third, they should keep the useful exchange of information flowing by focusing on enhancing the influence of the minority team member. Here is how the three elements can play out.

Match team to task. Research indicates that exploration (fact finding and learning) requires the creation and emergence of diverse perspectives at the level of knowledge, skills and abilities—and is best achieved by teams of heterogeneous individuals. In contrast, exploitation (applying the learning to accomplishing a task) is easier for homogeneous teams. Recently Michael L. Tushman of Harvard Business School and his colleagues noted the advantages of an alternative form of organizational architecture that includes

Nonvisible types of diversity, such as education or personality, can enrich creative group collaboration.

(The Authors)

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A leader can bridge diversity stresses by focusing the team on overarching group goals rather than on personal ones.

both kinds of teams—exploration and exploitation—integrated by a top management team. Such an ambidextrous organization has the advantage of being designed to manage the contradictions that many scholars argue are required to create long-term organizational effectiveness.

Build bridges. Perhaps one of the most disappointing findings in recent years about group decision making is that groups working together typically focus on shared, rather than unshared, information. For example, in 1996 Deborah H. Gruenfeld, Katherine Y. Williams and both of us compared the information exchange and decision making of three-person teams. We found that

groups composed of socially interconnected individuals outperformed groups of strangers in “hidden profile tasks”—those in which various members have different pieces of the information that would be necessary for the success of the project. But groups composed of strangers outperformed the socially tied groups when all information was common to all members. We believe that teammates who were socially connected felt a greater sense of security that led to their greater readiness to take the social risks involved in sharing their unique information.

A leader can similarly bridge diversity by bringing superordinate goals to the team. Such

GETTY IMAGES

goals might be task-related, organizationally relevant, or focused on work values. For example, team members at the World Bank from different national, religious and functional backgrounds connect with one another by focusing on their overarching goal of working to end poverty and to improve economic development around the planet. In another case, in 2005 Jennifer Chatman of the University of California, Berkeley, and Sandra Spataro of Cornell University learned that demographically distinct individuals (for exam-

ful, and organizations and their leaders must provide sufficient incentives to overcome it. For example, one company we know asks all its senior managers to mentor junior managers and to prepare at least three individuals to be ready to move up into their jobs. Part of each manager's performance evaluation is based on how well she or he has mentored junior staff. This company also realized a few years ago that more diversity was desirable at the top and that it was not happening naturally. So the firm requires that at least one of

Employees exposed to opposing minority views reap the creativity-boosting benefits of diversity.

ple, those who differed from their co-workers by race, nationality or gender) behaved more cooperatively when their business unit emphasized collectivistic rather than personal cultural values.

Create an open environment and forge alliances. Studies have consistently shown that employees exposed to opposing minority views reap the creativity-boosting benefits of diversity: they exert more cognitive effort, attend to more aspects of a situation, think in a divergent way, and are more likely to detect novel solutions or come to new decisions. Key to such achievement is enabling the person who is different to interact with, and influence, the rest of the team. If teams cannot create an environment that is tolerant of divergent opinions and emphasizes interdependence to reach a cooperative goal, then the individuals who carry the burden of having the unique perspectives may be reluctant to pay the social and psychological costs necessary to share their viewpoint.

Ultimately, the team leader has to support the notion that the minority opinion holder must be heard. A coalition, or alliance, with the leader helps to confer status and opens the door to respect for the minority. Setting a group norm of openness and learning also helps to enhance the ability of the minority individuals to make themselves heard. The overall opinion of the group may not move entirely to the minority point of view, of course, but a fully participating minority should facilitate decision making.

Embracing Change

Most important, organizations and their leaders must become part of the solution: they must encourage and reward change. Inertia is power-

the three junior staff being mentored be a woman or underrepresented minority. This strategy fostered diversity throughout the organization and has also, by its very nature, improved the amount of interaction between senior level managers and underrepresented minorities, to the benefit of its operations.

David A. Thomas and Robin J. Ely of Harvard Business School have argued that companies that develop a "learning and effectiveness" culture will create an environment that places high value on people's underlying identities and outlooks. Within such a culture, diversity is connected to work perspectives, and employees' differences can contribute to the organization's vision and strategy. In fact, in these organizations, members of minority groups are able to challenge how things are done and the ways in which "reality" is perceived. Thus, learning and change are much more likely.

Naturally, this paradigm shift requires several (perhaps difficult) preconditions. Among them is having corporate leaders who seek a variety of opinions and insights and who recognize the challenges that expressing such opinions can present for an organization. In addition, the culture must value openness and stimulate personal development. These requirements may seem like a tall order, but they set the stage for companies to truly realize the tremendous assets of their members' diversity. **M**

(Further Reading)

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SHOULD WE

HOW A BRAIN SURGEON ASSESSES THE RISK OF A PROCEDURE, AND INFORMS HER PATIENT ABOUT IT, CAN BE AS TRICKY AS THE SURGERY ITSELF BY KATRINA FIRLIK

I never even met one of the patients who had the most enduring impact on me. I was just a fourth-year medical student on rotation with the neurosurgery service, excited to participate in a cool, complex case. At my level, I would be relegated to scrubbing in and watching. The chief resident made me feel like part of the team, though, by discussing the case with me and granting me the dubious honor of placing a catheter in the patient's bladder, a lowly but necessary task. I also took the initiative to write some orders in the chart based on what I knew the woman would need after surgery. These orders would turn out to be unnecessary.

I learned from my chief resident that the patient, intubated and asleep in front of me, was young—a teenager really—who decided to undergo surgery only after painful deliberation. Years earlier she had been diagnosed with a large malformed tangle of blood vessels in her brain—an arteriovenous malformation, or AVM. Unfortunately, this AVM was of an extreme type—very large and in a very dangerous location. The situation is informally known among neurosurgeons as a “handshake AVM”: as the patient walks out of the neurosurgeon's office after a consultation, a handshake is all the surgeon has to offer.

The patient and her parents had lived in fear, never knowing if or when this malformation would decide to bleed. They knew that a bleed could be fatal. They also knew that surgery could be fatal. They respected their doctor's seasoned opinion that surgery wasn't an option for her. They understood his reluctance to risk having his own hand in her death or, worse, her neurological devastation if surgical removal were attempted. The psychology surrounding brain

CORBIS

OPERATE?



Individual personality, more than science, can be the driving factor in electing to undergo brain surgery.

Surgeon Firlik:
“The risks have to be laid out plain, in the open. A mentor told me that if the patient isn’t crying by the time you’re done going over the consent form, you haven’t done your job.”



surgery can sometimes be as difficult as the mechanics of it, as I must remind myself every day in my practice.

Now or Later

A clear example of that psychology is that one surgeon’s handshake can become another surgeon’s challenge. When this same woman’s original neurosurgeon left town to practice elsewhere, she and her parents sought the advice of another physician, one known for both his superlative microsurgical skills and his willingness to take on the most difficult cases. It was unusual for him to turn away a case; on one rare occasion, in advising a patient against surgery, he was rumored to have told her: “You don’t need me. You need Jesus Christ.”

I suspect the young woman and her parents were impressed by this surgeon’s confidence and reputation. Their impression, combined with the chronic unease that arose from doing nothing, must have tipped their decision toward surgery. In essence, a decision like this one comes down to: Do you want to take your risk up front, all at once (surgery), or slowly, over time (wait and watch)? Individual personality, more than science,

can be the driving factor in making such a choice.

The operation was a technical tour de force. The AVM, which had probably been there since birth, did not give in easily. It had spent its entire existence within the dark confines of the woman’s skull, sharing space with her brain, and her brain had unwittingly accommodated its presence. Although a potential threat to her life, the malformation was a native and natural part of her, not a recent invader.

The surgeon worked for hours, meticulously, under the brightly lit focus of the surgical microscope. He closed off one abnormal blood vessel after another, making sure to interrupt the complex inflow to the beast first, knowing that interrupting its outflow too early could provoke a bloody explosion. The final vessels were closed off and the tangled mass removed. I was surprised by the size of the depression left behind. The woman’s head was closed up, and she was wheeled out to recovery.

After witnessing this surgeon’s skill with my own eyes, I agreed that his reputation, and even his cockiness, was well deserved. If I needed brain surgery, he would be my surgeon. I thought about how satisfying it must be for him to go out to the family, announce his success and vindicate their most difficult decision. They had put their daughter’s life in his hands, and he was able to offer her a life without fear of the malformation. Others had warned strongly against surgery, citing unacceptable risk. The family went ahead anyway and could now be grateful that they had made the right decision.

The patient woke up gradually over the next half an hour, recovering slowly after hours of anesthesia. She wasn’t awake for long, though, before the nurse noticed early signs of trouble in her neurological examination. Minutes later she was unresponsive. A head scan revealed a catastrophe: massive bleeding into the brain, including the delicate brain stem. The surgeon went through all the right motions of a heroic rush back to the operating room, but the damage had been done and he knew it. The bleed was fatal.

Despite all good intentions and a technically successful operation, the woman’s brain could not tolerate the perturbations in circulation that accompanied removal of the large tangled mass of vessels. Maybe an otherwise normal artery in

KIT KITTLE



In the OR (*Firlik, left*): “Infection is always a risk. If you are unlucky, should you blame your surgeon? Should you call your lawyer? I have never been sued, but I expect to be.”

her brain, not accustomed to the new pressure dynamics, broke open. Or a critical vein near the malformation may have clotted off, leaving too few outflow options for the brain’s rich blood supply. Whatever the explanation, I imagined that this was the AVM’s final demand for respect, with her scan representing a “don’t touch” warning to surgeons tempted to offer other patients like her more than just a handshake. It was also a tragic introduction to the mantra I would hear again and again through my training: “The patient is the one taking the risk, not the surgeon.”

Years later, as a senior resident, I met another patient with a handshake AVM. She had resigned herself to inaction long ago. This woman’s AVM was so large that it extended across the corpus callosum, one of the structures that connect the two hemispheres of the brain. Although she was otherwise a healthy and active woman in her 30s, she had lived her life with full knowledge of the tangled mass that would always be with her.

This woman had never suffered a devastating bleed. Instead there were a few defined episodes in which the malformation leaked small amounts of blood into the brain. (This scenario is typical for the largest of AVMs. The smaller ones are more likely to cause larger bleeds for various reasons.) Luckily, these small bleeds were in the relatively resilient frontal lobes, and the patient suffered bad headaches but no significant neurological conditions. When I met her, she was in the hospital for a few days after one of these bleeds,

and my job was to check on her and make sure her blood pressure and her headaches remained under good control. That’s about all we had to offer, and, luckily, that’s all she needed.

Had these two patients, victims of random developmental circumstance, been given the chance to meet each other, what advice would the elder have given to the younger? It is clear that the brain can accommodate quite nicely to the overbearing presence of a malformation, but can the mind be trained to accommodate just as well? When inaction is the best action, how do you prevent fear itself from becoming an illness? Does the fear simply wear out, or does it have to be forced out?

Blunt Is Best

Knowledge is power, but it can also foster fear. Surgeons are obligated to educate patients about their condition and treatment options, but then doctors are faced with managing the anxiety that goes hand in hand with that knowledge. I have found that handling a patient’s anxiety can be more complicated, and sometimes even more time-consuming, than the surgery itself. Some

(The Author)

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As adviser: "Some surgeons prefer patients under anesthesia to patients wringing their hands over a decision. Others find those interactions rewarding. I tend toward the latter."



surgeons loathe this part of the job. It reminds them of all the reasons they didn't go into, say, psychiatry. They prefer patients under anesthesia to patients wringing their hands, crying and reading off a list of questions from everyone in their family. Others find those interactions rewarding. I tend more toward the latter camp, but I do empathize with those in the former.

Because anxiety management is not always enjoyable, some surgeons don't spend much time on it. I remember, as a resident, having to recalibrate a patient's thoughts. She was convinced that she was dying of a brain tumor. She had a small benign tumor, called an acoustic neuroma, on one of the nerves at the base of her brain. She had no symptoms. The tumor was discovered incidentally, when her head was scanned for other reasons. She was elderly, and a surgeon at another institution recommended doing nothing for it. She left his office thinking, "I have a brain tumor, and nothing can be done for me."

I saw her and her extended family a few months later, when a relative urged her to seek an opinion at our institution. She looked around at her loved ones in the room and expressed regret that this would probably be the last Christmas she would spend with them, as death was near.

I went over her MRI and examined her. I explained the reality of her small benign tumor at the base of her brain (not *in* her brain), and told her that it could have been there for quite a while. Most likely, she would die years down the line from a totally unrelated cause, before this little tumor could ever cause a significant problem. I went over all the options, and we settled on the one everyone

was most comfortable with for the time being: observation. I was happy to be of service, as it is always gratifying to extend someone's life expectancy without even having to pick up a scalpel.

During my training, I took to observing how different neurosurgeons interacted with their patients in discussing the risks of surgery. I knew I would have to devise my own personal style, but I figured I could pick up on what seemed to work and what didn't. On one extreme was the warm hand-holder who peppered religion-speak into his counseling about what could possibly go wrong. ("We'll get you through this, with God's grace.") That style did work wonders, especially with the older ladies, but I could never adopt it myself. The same surgeon was effective in conversation in other, more creative ways as well. I observed him discussing a difficult situation with a patient and her very large, extended Italian family. He was trying to get across the fact that the tumor at the base of her brain would be tricky to remove because of all the nerves draped across it. After thinking about it for a few seconds, he explained, "It's like trying to get at a large meatball when there are strings of angel-hair pasta in the way."

On the other extreme was the guy who, I'm a bit ashamed to admit, was entertaining to watch in a sadistic sort of way. There is only one word to describe his style: blunt. Here is how he would describe the risks of surgery for an aneurysm of the brain, just prior to having a patient sign her consent: "You could have a stroke. (Pause.) You could have permanent brain damage. (Pause.) You could become a vegetable. (Pause.) You could die." Although these statements were technically

COURTESY OF GREENWICH HOSPITAL, GREENWICH, CONN.

correct, the monotone voice with which they were spoken, and the sharklike demeanor that went with them, exemplified his uncanny ability to make a patient and her family burst into tears.

Needless to say, I didn't adopt this style wholesale, either, but I did appreciate the warning this surgeon left me with: if the patient isn't crying by the time you're done going over the consent for surgery, then you haven't done your job. Although I don't force an upwelling of tears from each and every patient, I agree with the spir-

one's fault. There is no such thing as bad luck.

Based on the alarmist tone of her voice, I imagined that in *her* mind, the surgeon willfully smeared bacteria into the surgical site, leading to fever, pus and a red, swollen incision. The truth is that infection remains (and will always remain) a risk of any surgical procedure. Although all measures are taken to bring that probability as close to zero as possible, it still hovers around 1 percent (or slightly higher or lower, depending on the surgical site, the circumstances and how healthy the

The brain can accommodate malformation, but can the mind? How does a patient overcome fear of inaction?

it of the advice: the risks of surgery have to be laid out plain, in the open, and cannot be taken lightly. And even though some patients prefer not to hear all the risks and just want to get the signing over with (worrying that if they hear too much, they'll change their mind), I think it's in their best interest to know everything anyway.

Furthermore, from a surgeon's point of view, the last thing you want is for a patient to come back after surgery saying she had no idea she could end up with: an infection, headaches, nerve damage, a numb foot, an ugly scar, a less than perfect outcome (take your pick). The next person the surgeon will hear from is a lawyer.

Sue Me Not

A patient's attitude, of course, complicates the discussion over risk. I saw a patient recently who had had spine surgery a few years earlier. As is often the case, the original reason for the surgery—advanced arthritis that can occur with age—continued to worsen. She was now faced with a second possible operation, for a neighboring part of her spine. I knew the surgeon who had performed the first operation, a highly reputable colleague, and I voiced some question as to why she wasn't in his office instead.

"Well, *he* gave me a wound infection, so you can be sure I won't be going back to *him!*" This sort of statement, and the vehement emotion that goes with it, raises a red flag. It might be easy for me to fall into the trap of flattery (the patient specifically chose me over the other surgeon), but the reality is that this is the type of patient who believes that the concepts of risk and complication are neatly and inextricably linked to another concept: blame. If something bad happens, it's some-

patient is). Surgeons feel terrible when a patient develops an infection, but they normally don't feel guilty. While it's true that in very rare cases, careless breaches in sterile technique are to blame, and certain individuals can be held liable, those are the very rare exceptions.

So if you are the unlucky individual who falls into that 1 percent because bacteria that naturally live on your skin (the usual source) infect your wound, should you blame your surgeon? Should you call your lawyer? Should you expect someone to pay up? One reason physicians are unhappy these days is that the definition of malpractice has changed. It is no longer defined as truly negligent or improper behavior. Now a poor outcome alone triggers claims of "malpractice." The quality of the care may be irrelevant.

I have never been sued, but I expect to be. The entire new generation of surgeons expects to be sued. Our elders tell us it's just a matter of time. It doesn't matter how good we are or how carefully we practice. For that reason, I'm always trying to figure out which of my patients might be most likely to sue me. If it's really obvious (they gloat about the lawsuit they won against Dr. So-and-So when surgery wasn't everything they had dreamed it would be), then I'm likely to steer clear of them and recommend definitive treatment elsewhere. Most of the time, though, it's not so obvious, and you have to go with your gut. Unfair? Maybe. Paranoid? Not at all. **M**

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How the brain decides what to focus conscious attention on

Coming to ATTENTION

By Andreas K. Engel, Stefan Debener
and Cornelia Kranczioch

With an impish smile, the professor announced that he was about to carry out a little experiment. He asked his class to watch a short video of two basketball teams and to count how many times the players in white T-shirts passed the ball. The students found that it wasn't easy to keep their eyes on the moving ball, but most of them believed they counted correctly.

After the show, the teacher turned to face everyone again: "What did you think about the gorilla?" There was a shocked silence. He restarted the video, and after a few seconds a collective groan rippled through the room: as the audience now realized, a person in an ape costume had walked right across the court, pausing in the middle to pound on his chest.

Psychologists Daniel J. Simons and Christopher F. Chabris showed this film at Harvard University for the first time in 1999. They were surprised by the results: half the observers missed the furry figure the first time they watched. How was that possible?



What happens in our brains when we deliberately concentrate on something?

As cognitive neuroscientists, we would like to know what is behind such phenomena: What happens in our brains when we deliberately concentrate on something? Does some mechanism inside our heads decide which information reaches our consciousness—and which does not? And do our intentions, needs and expectations influence what we perceive? Recent research offers some fascinating insights.

Homing in on Attention

Psychologists began seeking answers to such questions as long ago as 1890, when American philosopher and psychologist William James wrote about important characteristics of attention in *The Principles of Psychology*. James concluded that the capacity of consciousness is limited, which is why we cannot pay attention to everything at once. Attention is much more selective: it impels consciousness to concentrate on certain stimuli to process them especially effectively. James and others also distinguished between types of attention. Some of them are “self-created”: a penetrating odor, a loud siren, a woman in a bright red dress amid people clad in black. (Many researchers now call this process “bottom-up,” because the stimuli battle their way into our consciousness automatically because they are so striking.) Alternatively, we can actively and deliberately control our focus (called “top-down,” because higher brain regions are involved at the outset). For example, at a noisy party, we can tune out background noise to listen to the conversation at the next table.

Neuroscience did not take up this topic until much later. In 1985 a research team led by Robert Desimone at the National Institute of Mental Health was first to observe how single neurons in the visual cortex of rhesus monkeys changed their activity depending on what the primates were looking at. Desimone and his collaborator Jeffrey Moran discovered that certain neurons in the V4 area of the visual cortex—an area important for the perception of color—fired more frequently when the test animal gazed fixedly at a colored target. The same nerve cells exhibited much weaker activity when the ape noticed the target but did not look right at it. Other researchers later discovered that active attention was not only reflected in the higher levels of visual processing, such as in the V4 area, but could also be traced down to stimulus processing in the lowest levels in the cortical hierarchy.

Synchronous Firing

All these studies linked attention to an increase in the firing rate, or activity, of neurons. Now the latest neurobiological research points to another significant factor in attention: huge numbers of neurons synchronize their activity. Many neuroscientists believe that study of this phenomenon will provide the answer to one of the biggest riddles of attention research, the so-called binding problem.

Imagine that a grasshopper suddenly lands on the table in front of you. Before the insect can arrive in your consciousness as a fully realized, three-dimensional entity, several different areas

GETTY IMAGES (preceding page); "GORILLAS IN OUR MIDST: SUSTAINED INATTENTIONAL BLINDNESS FOR DYNAMIC EVENTS," BY D. J. SIMONS AND C. F. CHABRIS, IN PERCEPTION, VOL. 28, NO. 9, PAGES 1059-1074, 1999. COURTESY OF DANIEL J. SIMONS (this page)

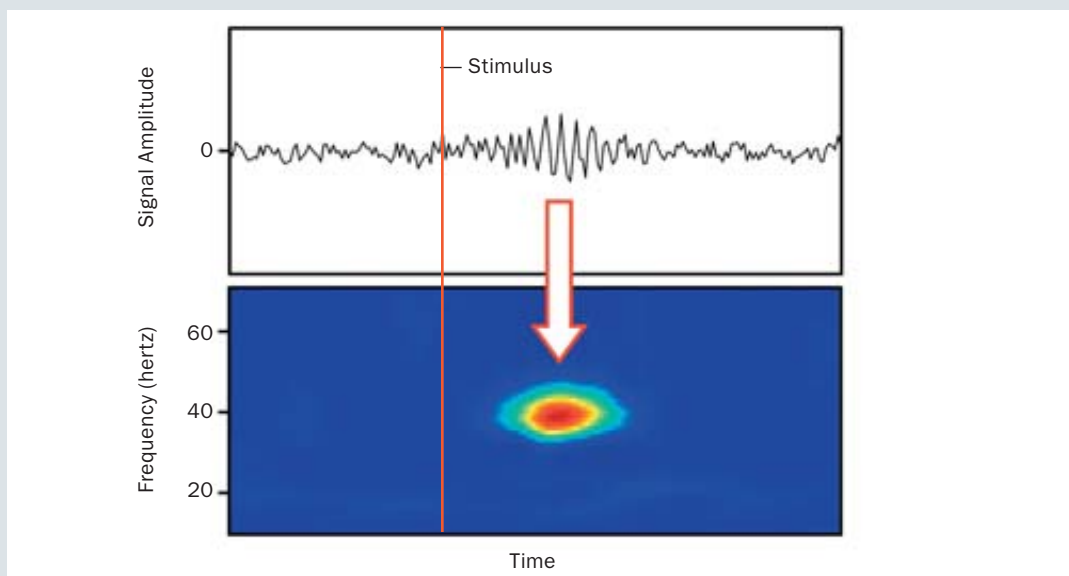
Follow the Ball

Ask a friend to count the number of passes by the team wearing white shirts in the video at http://viscog.beckman.uiuc.edu/djs_lab/demos.html (but don't warn him about the ape). He probably will not notice the interloper.



Nerve Cells in Synchrony

Active regions in the brain generate electrical signals that electrodes attached to the scalp can read (*top right*). After recording EEG measurements using many electrodes, scientists can reconstruct the originating location of the signals using mathematical methods (*top left*). Sensory stimuli lead to oscillatory responses in the EEG (*top graph*), which are the result of synchronous activity by many neurons. The frequency distribution of the measured signal can be examined for each electrode, and the change in this frequency distribution during the time after presentation of the stimulus is represented. Warm color tones indicate an increase in activity in the time-frequency region of interest (*bottom graph*).



ANDREAS K. ENGEL, STEFAN DEBENER AND CORNELIA KRANZIOCH

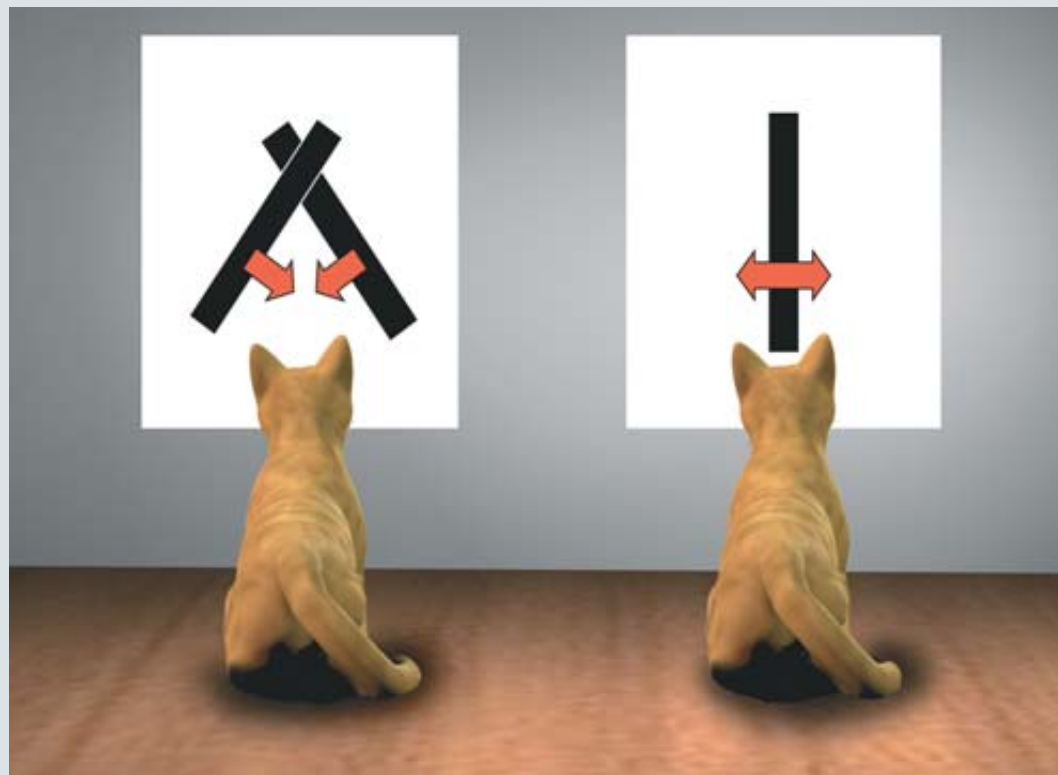
of the brain must be active. One processes the insect's color, another its size, yet another its location, and so on. How does the brain bind all these individual characteristics together into a single impression of a green grasshopper?

Twenty years ago Christoph von der Malsburg, a computer scientist and brain theorist, now at the Ruhr University in Bochum, Germany, sug-

gested a solution. By synchronizing their activities, nerve cells could join into effectively cooperating units—so-called assemblies. Subsequently, a number of research teams, among them the group at Wolf Singer's laboratory at the Max Planck Institute for Brain Research in Frankfurt, have demonstrated that this "ballet of neurons" in fact exists. Peter Koenig, Singer and one of us (En-

Cats with a Binding Problem

At the left in this schematic representation, a cat perceives two targets moving in different directions (*arrows*) across a screen. One group of directional neurons in its visual cortex reacts to the movements of one target, a second to those of the other. Both nerve cell populations fire independently of each other. But the groups synchronize their activity when they look at the vertical target in the right image, which moves to the left or right (*arrows*).



gel) carried out an especially decisive experiment at the end of the 1980s [see box above]. We presented a cat with various targets to observe. When we showed it a single object, neurons in its visual system responsible for analyzing characteristics synchronized their activities in a pronounced way. When we gave the animal two separate objects to look at, however, the common rhythm broke down. The synchronization changed to a pattern of rapid oscillatory fluctuations at characteristic frequencies between 30 and 100 hertz, a region that brain researchers call the gamma band.

Then, in the early 1990s, Nobel laureate Fran-

cis Crick (who died in 2004) and computational neuroscientist Christof Koch of the California Institute of Technology expanded on Malsburg's hypothesis with a then provocative idea. The two scientists posited that only signals from "teams" of neurons that cooperated especially well possessed enough strength to reach the consciousness.

Recent findings lend empirical support to the Crick-Koch hypothesis. Between 1995 and 1998, Pascal Fries—now at the F. C. Donders Center for Cognitive Neuroimaging in Nijmegen, the Netherlands—and Singer, Engel and others at Max Planck carried out some of these experiments. The investigators took advantage of an effect called binocular rivalry: if the right eye and the left eye are equipped with special glasses that let each see only one of two very different images, the subject cannot meld them into a single perception. The brain resolves this dichotomy by favoring input from one eye and suppressing input from the other. As a result, the volunteers always saw just one

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ANDREAS K. ENGEL AND CORNELIA KRANCZIOCH

of the pictures at a time. First they would see one image and then, a few seconds later, the other.

Two Eyes Vying

How is binocular rivalry waged at the neuronal level? We compared two groups of nerve cells in the visual cortices of cats: one group dealt with the characteristics of the left image, the other with those of the right. From an animal's behavior we could tell which image it was looking at during any given moment. Whichever side occupied the feline's attention showed superior neuronal synchronization. In contrast, when we then compared the neurons' firing rates, we observed no difference. This result demonstrated that the degree of neuronal synchronization decisively influences which incoming signals are further processed and thus becomes relevant to the consciousness's perception.

Fries also showed that active, intentional control of attention can influence gamma synchronization. He worked in Desimone's lab with macaques that had learned to direct their attention to a particular spot on the monitor screen in response to a signal; a stimulus would appear at that location after a short delay. If this stimulus appeared at the

expected location, the gamma oscillations were clearly stronger. Synchronization immediately weakened, however, as soon as the research animals switched their attention to other stimuli.

For humans, such experiments using implanted electrodes are possible only during brain surgery. As a result we usually measure gamma activity by means of electroencephalography (EEG). We recently carried out an attention experiment in which subjects read letters that flashed briefly on a computer monitor [see box below]. Most of the letters were black, but now and again we inserted a few green letters, which we asked the subjects to count. Analysis of the EEG signals taken during the tests showed that only the unexpected appearance of green letters produced an increase in the high-frequency part of the gamma band.

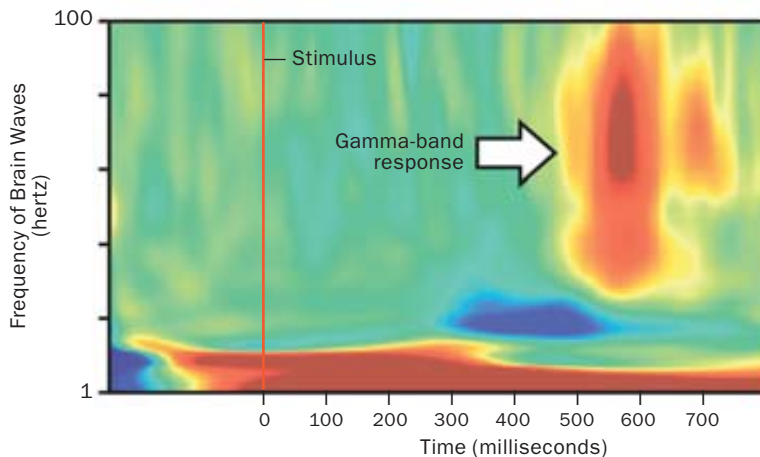
Expectant Neurons

The effect of expectation reveals itself especially clearly in an experiment using acoustic stimuli. We asked listeners to pay particular attention to high tones in a series of more or less similar tones. When they heard the target tone, a high-frequency gamma-band activity appeared in the brain; in contrast, unexpected loud noises,

Letter by Letter

When test subjects focus attention deliberately, an EEG can read especially rapid brain waves. If the volunteers are asked to count green letters that appear among a series of black letters, the stimuli arouse high-frequency activity in the region between 30 and 100 hertz, the so-called gamma-band response.

G H P W U X S L A M Q B J Y F T ...



which automatically call attention to themselves, did not elicit this effect.

Regardless of which sensory system is involved, the reinforced rhythmic synchronization in the gamma band that we measured seems to be a good indicator of active attention. When a person deliberately directs attention to a stimulus, not only do the firing rates of individual neurons in the brain change, but the synchronization also improves for all the neurons taking part in the coding for the same stimulus. We liken the effect to a symphony orchestra that soon arrives at a common tempo after the individual instruments begin playing.

In what ways might intentions and needs influence attention? With the help of functional magnetic resonance imaging (fMRI), we wanted to locate brain regions involved in conscious perception of a target stimulus. To do so, we needed a research technique to compare two conditions: one that led from active attention to conscious awareness of a stimulus, and a second, in which the same stimulus did not penetrate the consciousness. We used a phenomenon called attention blink. In the experiment we once again displayed a series of letters to subjects while we observed them with fMRI. This time, however, only a single green letter appeared among rapidly changing black letters, and the subject had to tell us, at the end of the test run, whether or not it was a vowel. At the same time, the subject was to look for a black X that popped up at different times after the green letter.

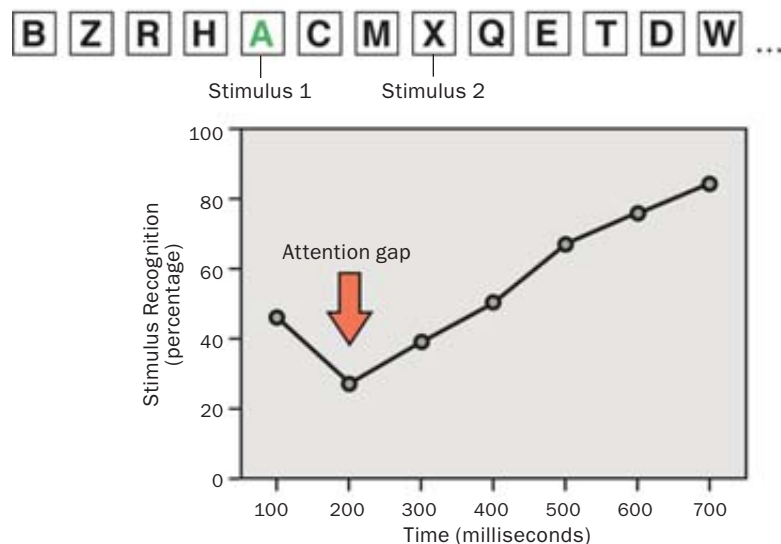
During the experiment, the attention of our subjects showed clear gaps—the “blinks”—as a result of their intentional, conscious focus on the task [see box below]. If the black X appeared very soon—within a third of a second—after the green letter, about half the time the participants did not notice it. If there was a longer period after the first stimulus, their recognition rate improved.

At the end of the experiment, we compared the fMRI values for each run-through in which the subjects perceived the X with those in which it was shown but not noticed. We saw clear differences in activity in a few brain regions, all in the frontal and the parietal cortices. Scientists have been aware of these regions’ importance in controlling attention for a long time: for example, some patients who suffer damage to certain parts of their parietal cortex from a stroke can no longer pay attention to any stimuli in certain areas of their visual fields, which means they cannot consciously perceive them. We were surprised, however, when we found a difference in the limbic system—in the amygdala, to be precise, which is normally involved in processing emotional reactions. The state of our emotional system probably influences the control of attention and which sensory signals are allowed to reach consciousness.

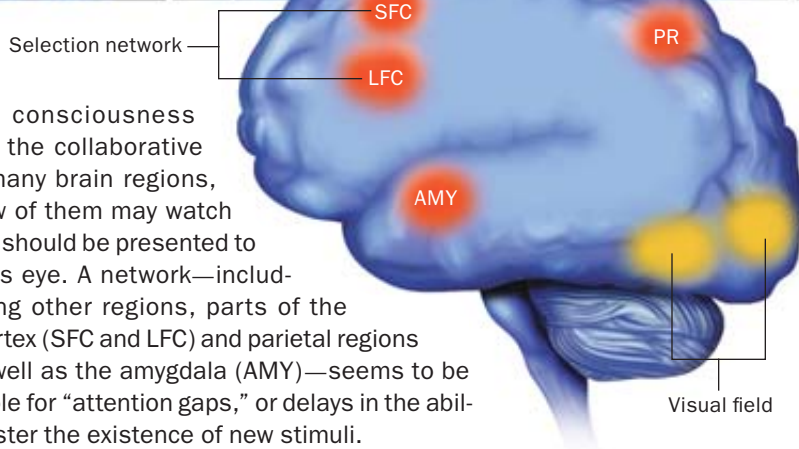
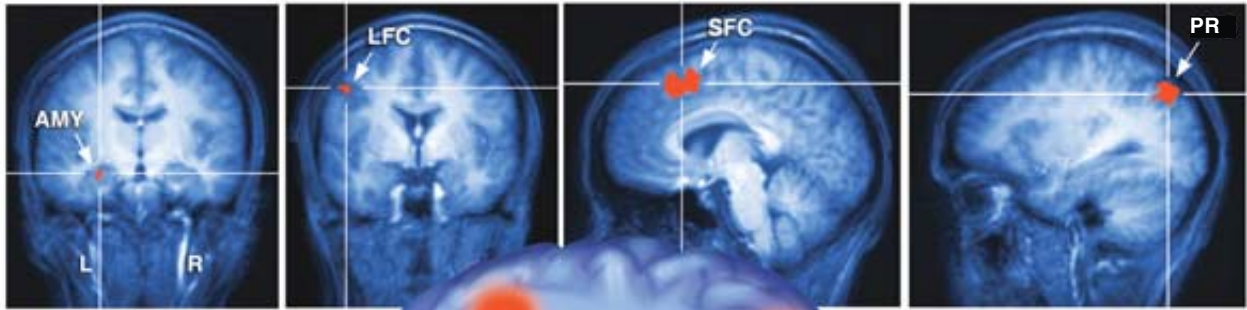
The experiments we describe provide another puzzle for researchers who are seeking the neuronal basis of consciousness: the gamma oscillation that is closely associated with conscious percep-

The Mind’s Eye Blinks

If subjects in an experiment receive two tasks, one coming very soon after the other, their attention capacities are strained. If the second stimulus comes between 200 and 300 milliseconds after the first, the subjects’ ability to recognize it is especially weak. It is only when the two stimuli are separated by larger time intervals that they can be noticed reliably.



Neuronal Puppet Master



Although consciousness demands the collaborative work of many brain regions, only a few of them may watch over what should be presented to the mind's eye. A network—including, among other regions, parts of the frontal cortex (SFC and LFC) and parietal regions (PR), as well as the amygdala (AMY)—seems to be responsible for “attention gaps,” or delays in the ability to register the existence of new stimuli.

tion does not just depend on external stimuli but also on the flexible inner dynamic of the brain. We theorize that neurons are constantly and actively predicting where the visual stimuli they expect will appear. Fries and other researchers have in fact measured the synchronization effect in the visual area of animals even before they were presented with an expected stimulus. Probably, brain regions such as the frontal cortex or the limbic system exercise influence over synchronization in the sensory areas [see box above].

All incoming stimuli set their own temporal coupling patterns in motion. If these stimuli correspond to those that the expectation has created, the incoming signals are reinforced by a resonance effect and conducted onward. If the expectations are not met, however, the brain suppresses the incoming neuronal messages. This process was at work in the gorilla experiment. The subjects were not looking for a person in a gorilla suit. Their brains were engaged in tracking the moving players in white. Any information about an ape that hit their retinas was out of sync with neuronal expectations, found no resonance and went unnoticed.

Neuronal synchronization brings order to the chaotic mental world. In fact, cognitive deficits

and disordered thoughts among schizophrenic patients appear to be connected to disturbed gamma-band coupling. The healthy brain is, however, anything but a passive receiver of news from the environment. It is an active system, one that controls itself via a complex internal dynamic. Our experiences, intentions, expectations and needs affect this dynamic and thus determine how we perceive and interpret our environment. **M**

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VIOLENT PRIDE

DO PEOPLE TURN VIOLENT BECAUSE OF SELF-HATE, OR SELF-LOVE? BY ROY F. BAUMEISTER

Several years ago a youth counselor told me about the dilemma he faced when dealing with violent young men. His direct impressions simply didn't match what he had been taught. He saw his violent clients as egotists with a grandiose sense of personal superiority and entitlement, but his textbooks told him that these young toughs actually suffered from low self-esteem. He and his staff decided they couldn't go against decades of research, regardless of what they had observed, and so they tried their best to boost the young men's opinions of themselves, even though this produced no discernible reduction in their antisocial tendencies.

The view that aggression stems from low self-esteem has long been common knowledge. Counselors, social workers and teachers all over the country have been persuaded that improving the self-esteem of young people is the key to curbing violent behavior and to encouraging social and academic success. Many schools have students make lists of reasons why they are wonderful people or sing songs of self-celebration. Many parents and teachers are afraid to criticize kids, lest it cause serious psychological damage and turn some promising youngster into a dangerous thug or pathetic loser. In some sports leagues, everyone gets a trophy.

A number of people have questioned whether these feel-good exercises are really the best way to build self-esteem. But what about the underlying assumption? When my colleagues and I began looking into the matter in the early 1990s, we found article after article citing the "well-known fact" that low self-esteem

causes violence. Yet we were unable to find any book or paper that offered a formal statement of that theory, let alone empirical evidence to support it. Everybody knew it, but nobody had proved it.

Unfortunately for the low-self-esteem theory, researchers have gradually built up a composite image of what it is like to have low self-esteem, and that image does not mesh well with what we know about aggressive perpetrators. People who have a negative view of themselves are typically muddling through life, trying to avoid embarrassment, giving no sign of a desperate need to prove their superiority. Aggressive attack is risky; people with low self-esteem tend to avoid risks. When people with low self-esteem fail, they usually blame themselves, not others.

Faced with these incongruities, we cast about for an alternative theory. A crucial influence on our thinking was the seemingly lofty self-regard of prominent violent people. Saddam Hussein is not known as a modest, cautious, self-doubting individual. Adolf Hitler's exaltation of the "master race" was hardly a slogan of low self-esteem. These examples suggest that high self-esteem, not low, is indeed an important cause of aggression.

We eventually formulated our hypothesis in terms of threatened egotism. Not all people who think highly of themselves are prone to violence. That favorable opinion must be combined with some external threat to the opinion. Somebody must question it, dispute it, undermine it. People like to think well of themselves, and so they are loath to make downward revisions in their self-esteem. When someone suggests such a revi-

PHOTOGRAPHS BY TINA WEST





sion, many individuals—those with inflated, tenuous and unstable forms of high self-esteem—prefer to shoot the messenger.

Pride Comes Before a Fall

It would be foolish to assert that aggression always stems from threatened egotism or that threatened egotism always results in aggression. Human behavior is caused and shaped by various factors. Plenty of aggression has little or nothing to do with how people evaluate themselves. But if our hypothesis is right, inflated self-esteem increases the odds of aggression substantially. For those aggressive acts that do involve the perpetrators' self-regard, we believe that threatened egotism is crucial. Obviously, this new theory could have implications for designing effective methods to reduce violence.

So how does a social psychologist establish whether low or high self-esteem leads to violence? Because there is no perfect, general method for understanding complex questions about human beings, social scientists typically operate by conducting multiple studies with different methods. A single study can be challenged, especially if competing views exist. But when a consistent pattern

emerges, the conclusions become hard to ignore.

Researchers measure self-esteem by asking a standardized series of questions, such as “How well do you get along with other people?” and “Are you generally successful in your work or studies?” The individual chooses from a range of responses, and the overall score falls somewhere on the continuum from negative to positive. Strictly speaking, it is misleading to talk of “people high in self-esteem” as if they were a distinct type, but I use this phrase to refer broadly to those who score above the median on the self-esteem scale. Statistical analyses respect the full continuum.

Many laypeople have the impression that self-esteem fluctuates widely, but in fact these scores are quite stable. Day-to-day changes tend to be small, and even after a serious blow or boost, a person's self-esteem score returns to its previous level within a relatively short time. Large changes most often occur after major life transitions, such as when a high school athlete moves on to college to find the competition much tougher.

Quantifying aggression is trickier, but one approach is simply to ask people whether they are prone to angry outbursts and conflicts. These self-reported tendencies can then be compared to the self-esteem scores. Most research has found a weak or negligible correlation, although an important exception is the work done in the late 1980s by Michael H. Kernis of the University of Georgia and his colleagues. They distinguished between stable and unstable self-esteem by measuring each person on several occasions and looking for fluctuations. The greatest hostility was reported by people with high but unstable self-esteem. Individuals with high, stable self-esteem were the least hostile, and those with low self-esteem (stable or unstable) were in between.

Take a Swig, Take a Swing

Another approach is to compare large categories of people. Men on average have higher self-esteem than women and are also more aggressive. Depressed people have lower self-esteem and are less violent than nondepressed people. Psychopaths are exceptionally prone to aggressive and criminal conduct, and they have very favorable opinions of themselves.

Evidence about the self-images of specific murderers, rapists and other criminals tends to be more anecdotal than systematic, but the pattern is clear. Violent criminals often describe themselves as superior to others—as special, elite persons who deserve preferential treatment. Many

murders and assaults are committed in response to blows to self-esteem such as insults, “dissing” and humiliation. (To be sure, some perpetrators live in settings where esteem and respect are linked to status in the social hierarchy, and to put someone down can have tangible and even life-threatening consequences.)

The same conclusion has emerged from studies of other categories of violent people. Street-gang members have been reported to hold favorable opinions of themselves and to turn violent when these views are disputed. Playground bullies regard themselves as superior to other children; low

conduct some. Brad J. Bushman, now at the University of Michigan at Ann Arbor, took the lead.

The first challenge was to obtain reliable data on the self-concepts of participants. We used two different measures of self-esteem, so that if we failed to find anything, we could have confidence that the result was not an artifact of having a peculiar scale. Yet we were skeptical of studying self-esteem alone. The hypothesis of threatened egotism suggested that aggressive behavior would tend to occur among only a subset of people with high self-esteem. In the hope of identifying this subset, we tested for narcissism.

(Violent criminals describe themselves as special, elite persons who deserve preferential treatment.)

self-esteem is found among the victims of bullies but not among bullies themselves. Violent groups generally have overt belief systems that emphasize their superiority over others. War is most common among proud nations that feel they are not getting the respect they deserve, as Daniel Chirot discusses in his fascinating book *Modern Tyrants*.

Drunk people are another such category. It is well known that alcohol plays a role in either a majority or a very large minority of violent crimes; booze makes people respond to provocations more vehemently. Far less research has examined the link with self-esteem, but the findings do fit the egotism pattern: consuming alcohol tends to boost people’s favorable opinions of themselves. Of course, alcohol has myriad effects, such as impairing self-control, and it is hard to know which is the biggest factor in drunken rampages.

Aggression toward the self exists, too. A form of threatened egotism seems to be a factor in many suicides. The rich, successful person who commits suicide when faced with bankruptcy, disgrace or scandal is an example. The old, glamorous self-concept is no longer tenable, and the person cannot accept the new, less appealing identity.

Vanity Unfair

Taken together, these findings suggest that the low-self-esteem theory is wrong. But none involves what social psychologists regard as the most convincing form of evidence: controlled laboratory experiments. When we conducted our initial review of the literature, we uncovered no studies that probed the link between self-esteem and aggression. Our next step, therefore, was to

Narcissism is a mental illness characterized by inflated or grandiose views of self, the quest for excessive admiration, an unreasonable or exaggerated sense of entitlement, a lack of empathy, an exploitative attitude toward others, a proneness to envy or wish to be envied, frequent fantasies of greatness, and arrogance. The construct was extended beyond the realm of mental illness by Robert Raskin of the Tulsa Institute of Behavioral Sciences in Oklahoma and his colleagues, who constructed a scale for measuring narcissistic tendencies.

We included that measure alongside the self-esteem scales, because the two traits are not the same, although they are correlated. Individuals with high self-esteem need not be narcissistic. They can be good at things and recognize that fact without being conceited or regarding themselves as superior beings. The converse—high narcissism but low self-esteem—is quite rare, however.

The next problem was how to measure aggression in the laboratory. The procedure we favored involved having pairs of volunteers deliver blasts of loud noise to each other. The noise is unpleasant and people wish to avoid it, so it provides a good analogue to physical aggression.

The noise was presented as part of a competi-

(The Author)

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tion. Each participant vied with somebody else in a test of reaction time. Whoever responded more slowly received a blast of noise, with the volume and duration of the noise set by his or her opponent. This procedure differed from that of earlier studies, in which the subject played the role of a “teacher” who administered noise or shock to a “learner” whenever the learner made a mistake. Critics had suggested that such a method would yield ambiguous results, because a teacher might deliver strong shocks or loud noise out of a sincere belief that it was an effective way to teach.

“One of the Worst”

To study the “threat” part of threatened egotism, we asked participants to write a brief essay expressing their opinion on abortion. We collected the essays and (ostensibly) redistributed them, so the two contestants could evaluate each other’s work. Each participant then received his or her own essay back with the comments the other person had (supposedly) given it.

In reality, we took the essays and randomly marked them good or bad. The good evaluation included very positive ratings and the handwritten comment, “No suggestions, great essay!” The bad evaluation contained low marks and the comment, “This is one of the worst essays I have read!” After handing back the essays and evaluations, we

with a large body of evidence indicating that violence against innocent bystanders is, despite conventional wisdom, quite rare.

A revealing incident illuminates the attitudes of the narcissists. When a television station did a feature on this experiment, we administered the test to new participants for the benefit of the cameras. One of them scored in the 98th percentile on narcissism and was quite aggressive. Afterward he was shown the film and given the opportunity to refuse to let it be aired. He said to put it on—he thought he looked great. Bushman took him aside and explained that he might not want to be seen by a national audience as a highly aggressive narcissist. The footage showed him using severe profanity when receiving his evaluation, then laughing while administering the highest permitted levels of aggression. The man shrugged this off with a smile and said he wanted to be on television. When Bushman proposed that the station at least digitize his face to disguise his identity, the man responded with an incredulous no. In fact, he said, he wished the program could include his name and phone number.

Would our laboratory findings correspond to the outside world? Real-life violent offenders are not the easiest group of people to study, but we gained access to two sets of violent criminals in prison and gave them the self-esteem and narcissism

(Narcissists **blasted people** who had insulted them) but did not attack an innocent third party.)

gave out instructions for the reaction-time test and the subjects began to compete.

The results supported the threatened-egotism theory rather than the low-self-esteem theory. Aggression (blasting noise) was highest among narcissists who had received the insulting criticism. Nonnarcissists (with either high or low self-esteem) were significantly less aggressive, as were narcissists who had been praised.

In a second study, we replicated these findings and added a new twist. Some participants were told that they would be playing the reaction-time game against a new person—someone different from the person who had praised or insulted them. We were curious about displaced aggression: Would people angered by their evaluation lash out at just anybody? As it happened, no. Narcissists blasted people who had insulted them but did not attack an innocent third party. This result agrees

questionnaires. When we compared the convicts’ self-esteem with published norms for young adult men (mostly college students) from two dozen different studies, the prisoners were about in the middle. On narcissism, however, the violent prisoners had a higher mean score than any other published sample. It was the crucial trait that distinguished these prisoners from college students. If prison seeks to deflate young men’s delusions that they are God’s gift to the world, it fails.

As our findings about self-esteem and violence have become known, others have scrambled to find support for the low-self-esteem theory. What little they find comes mostly from questionnaires, which to me is suspect. People with low self-esteem are more willing than others to admit to bad actions, including aggression; an individual scores low on self-esteem precisely by saying bad things about himself or herself. Behavioral mea-

sures, however, continue to link aggression to narcissism, and scoring high on both narcissism and self-esteem predicts the greatest aggression.

What about Deep Down?

A common question in response to these findings is: “Maybe violent people seem on the surface to have a high opinion of themselves, but isn’t this just an act? Might they not really have low self-esteem on the inside, even if they won’t admit it?” This argument has a logical flaw. We know from ample research that people with overt low self-esteem are not aggressive. Why should low self-esteem cause aggression only when it is hidden? The only difference between hidden and overt low self-esteem is the fact of its being hidden, so the cause of violence would not be the low self-esteem but the concealment of it. What is concealing it is the veneer of egotism—which brings us back to the threatened-egotism theory.

Various researchers have tried and failed to find any sign of a soft inner core among violent people. Martin Sanchez-Jankowski of the University of California, Berkeley, who spent 10 years living with various gangs and wrote one of the most thorough studies of youth gang life, had this to say: “Some studies of gangs suggest that many gang members have tough exteriors but are insecure on the inside. This is a mistaken observation.” Dan Olweus of the University of Bergen in Norway has devoted his career to studying childhood bullies, and he agrees: “In contrast to a fairly common assumption among psychologists and psychiatrists, we have found no indicators that the aggressive bullies (boys) are anxious and insecure.”

The case should not be overstated. Psychology is not yet adept at measuring hidden aspects of personality, especially ones that a person may not be willing to admit even to himself or herself. But at present there is no empirical evidence or theoretical reason that aggressors have a hidden core of self-doubt.

Although this conclusion contradicts the traditional focus on low self-esteem, it does not mean that aggression follows directly from an inflated view of self. Narcissists are no more aggressive than anyone else, as long as no one insults or criticizes them. But when they receive an insult—which could be seemingly minor—the response tends to be much more aggressive than normal. Thus, the formula of threatened egotism combines something about the person with something about the situation. Whatever the details of cause and effect, this appears to be the most accurate formula for predicting violence.

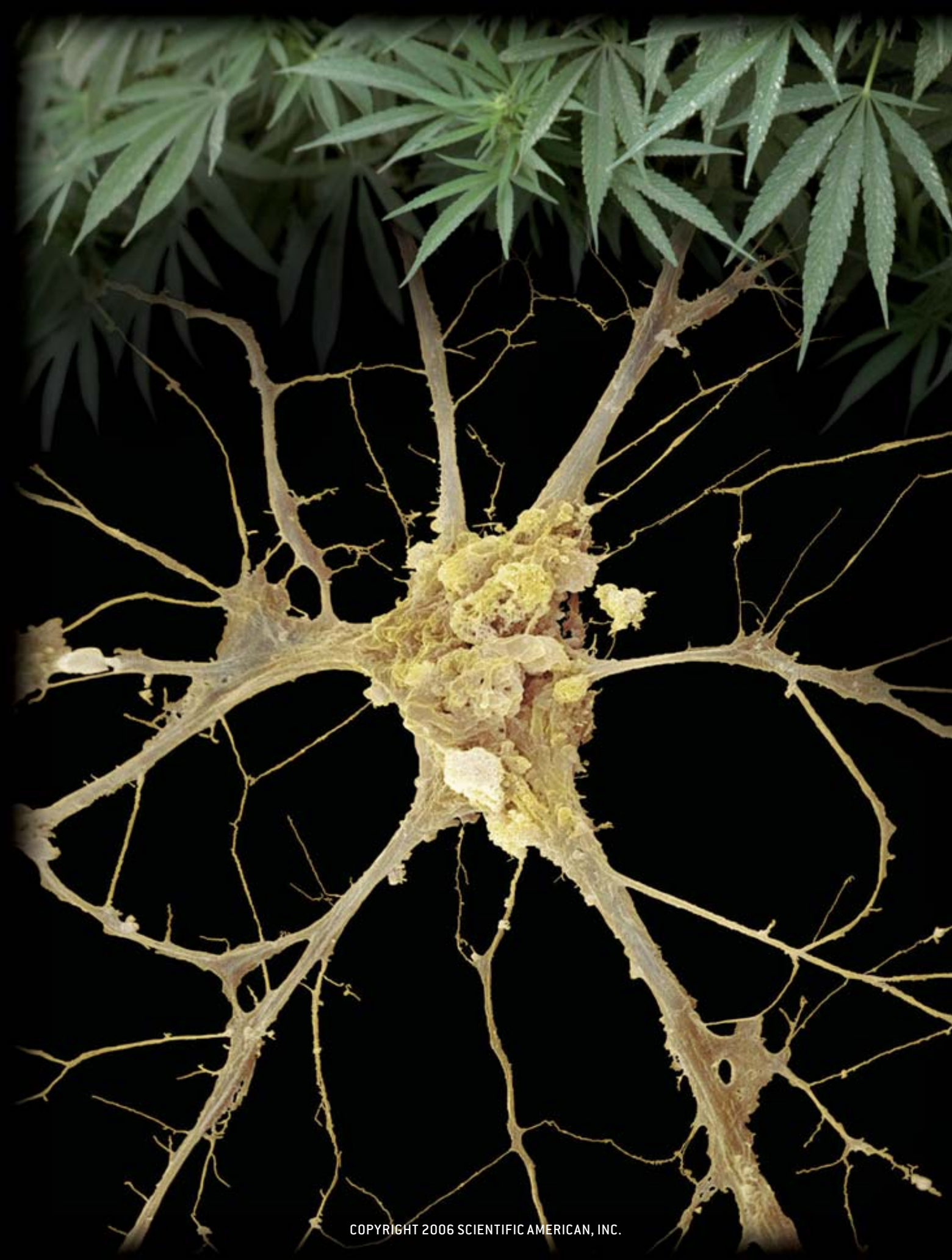


These patterns raise misgivings about how schools and other groups seek to boost self-esteem with feel-good exercises. A favorable opinion of self can put a person on a hair trigger, especially when this favorable opinion is unwarranted. In my view, there is nothing wrong with helping students and others to take pride in accomplishments and good deeds. But there is plenty of reason to worry about encouraging people to think highly of themselves when they haven’t earned it. Praise should be tied to performance (including improvement) rather than dispensed freely as if everyone had a right to it simply for being oneself.

A person with low self-esteem is not prone to aggressive responses. Instead one should beware of people who regard themselves as superior, especially when those beliefs are inflated, weakly grounded in reality or heavily dependent on having others confirm them frequently. Conceited, self-important individuals turn nasty toward those who puncture their bubbles of self-love. **M**

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Natural HIGH

**The brain produces its own “marijuana” to
protect neurons, and researchers hope to
exploit it to ease anxiety, obesity and addiction**

By Ulrich Kraft



C

hemically speaking, we are all potheads. Raphael Mechoulam of Hebrew University in Jerusalem discovered that astounding fact in 1992, and now the reasons why are finally emerging. Numerous experiments with genetically altered mice and rats have shown that when natural brain compounds, called endocannabinoids, are missing or their receptors are blocked, the animals are more susceptible to pain, cannot control their appetites, have trouble handling anxiety and are less able to cope with stress.

By fully understanding and then harnessing the endocannabinoid mechanisms, researchers are eager to devise new ways to reduce pain, calm anxiety, fight obesity, stop nicotine addiction and even treat traumatic shock and Parkinson's disease—without the unwanted side effects of smoking marijuana.

Signals in Reverse

To be precise, endocannabinoids do not mimic the effects of marijuana. It is the drug, derived from the hemp plant, that approximates the brain's endocannabinoid chemistry. A decade of study has shown that a specific receptor on certain neurons—the cannabinoid receptor 1, or CB1—binds to delta-9-tetrahydrocannabinol (THC), the active ingredient in cannabis, the dried leaf of marijuana. The same receptor binds to a class of fatty

ling appetite, and in the cerebellum, which governs muscle coordination. They are also prevalent in the hippocampus, important to memory formation, as well as in the amygdala, involved in emotion and anxiety. And they are found in the neocortex, the site of such cognitive functions as speech and integration of the senses. Given the endocannabinoids' roles, it is easy to understand the classic signs of a pot smoker who is high: calm demeanor, poor motor coordination, altered sensory perceptions and an eventual attack of the munchies.

What surprised investigators, when it became clear that the endocannabinoids were communicating between neurons, was that the direction of communication occurred in reverse. When a typical neuron fires, it releases neurotransmitters that are stored near the tip of its axon. The signaling chemicals cross a small gap, or synapse, and dock with receptors on the dendrite of the next neuron, causing it to fire, and so on down the chain. The endocannabinoids, however, are rapidly synthesized in the recipient neuron's cell membrane. They cross the gap in reverse, docking at the axon [see box on page 64]. Neuroscientists had thought this retrograde signaling occurred only during fetal development of the nervous system.

Using mice and rats in labs, researchers slowly figured out the reason for the retrograde communication. "A neuron that has just received a

(The human brain's cannabinoid system seems to fulfill multiple functions.)

acids produced by neurons—the endocannabinoids. Mechoulam named the one he discovered anandamide—after *ananda*, the Sanskrit word for "bliss." Subsequently, Daniele Piomelli and Nephi Stella of the University of California, Irvine, found a second compound, called 2-AG, with similar characteristics. THC happens to resemble these substances closely enough that the CB1 receptors latch onto it, unleashing similar or magnified effects on the toker's brain.

CB1 receptors are not everywhere in the brain—they exist in concentrated pockets in many varied locations. The distribution suggests that the human cannabinoid system fulfills multiple functions [see box on opposite page]. For example, numerous receptors exist in the hypothalamus, which plays a central role in control-

message can send one right back that says, 'Stop transmitting!'" explains Andreas Zimmer, a neurobiologist at the University of Bonn in Germany who helped define the backward mechanism. "The endocannabinoids are an inhibitory feedback loop. The second neuron reports back to the sender: 'Message received. Cease firing. I got it!'"

An Ancient Cure

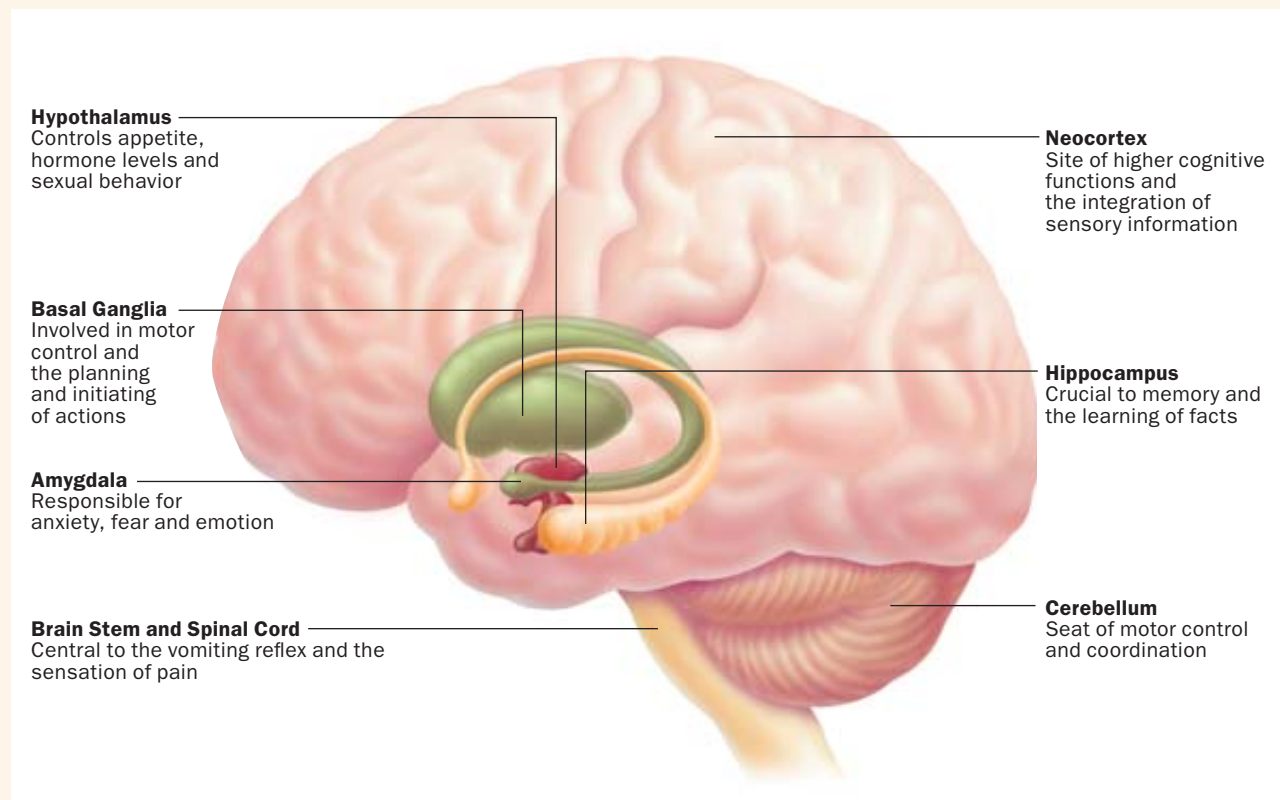
According to Ibn Al Badri, an Arab chronicler, people knew about the inhibitory effects of hashish, also derived from hemp, at the court of the caliphs in 15th-century Baghdad. For one thing, hashish reportedly stopped the epileptic seizures in the son of a high official. Such attacks arise when neurons fire in rampant unison across the brain—

VVG SPL Photo Researchers, Inc. (neuron); RIC ERGENBRIGHT Corbis (cannabis) (preceding pages)

Crucial Roles

Endocannabinoid receptors are concentrated in many brain regions, making them crucial to various functions. Their distribution also explains some of the

classic behaviors associated with smoking marijuana and the potential payoff of drugs that mimic endocannabinoid effects for patients with severe pain or other problems.



meaning no inhibition signal stops them. Today some epileptics can somewhat manage their attacks by smoking cannabis regularly. And yet for others, seizures worsen after this self-therapy.

Stress Protector

Still, experts now for the most part agree that the main function of the endocannabinoids is to protect neurons from excessive activity. The brain “has created a kind of emergency brake for use when needed,” says Beat Lutz, a physiological chemist at the University of Mainz in Germany who has also helped elucidate endocannabinoid mechanisms. If a neuronal storm threatens, the endocannabinoids are released to block it. According to Lutz, this protective mechanism plays an important role well beyond epilepsy. “It appears to be quite general,” the researcher explains. “If the brain has a problem, it produces endocannabinoids.”

Andrea Giuffrida, a pharmacology professor

at the University of Texas at San Antonio, has confirmed this theory working with Parkinson’s patients. In Parkinson’s disease, neurons in certain brain regions that produce the neurotransmitter dopamine die off. As a result, victims develop severe motor problems. A certain toxin that kills dopamine-producing neurons causes similar symptoms. So Giuffrida injected the toxin into lab mice a few minutes after giving them a synthetic cannabinoid. The cannabinoid prevented the toxin’s destructive effects. “The brains of the mice that had been treated with the marijuana-like substance could scarcely be distinguished from those of normal mice,” Giuffrida says. He hopes that his work will ultimately lead to compounds that stop the destruction of dopa-

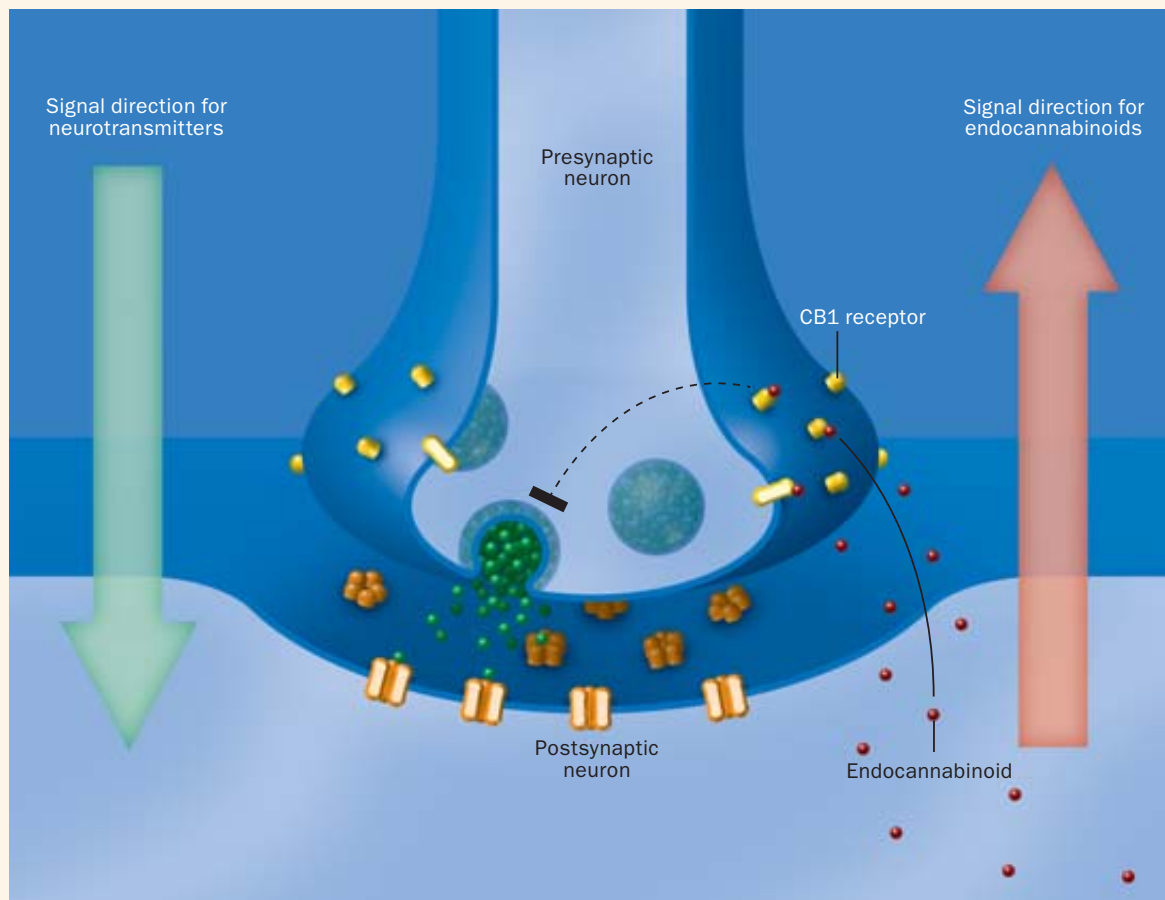
(The Author)

ULRICH KRAFT, a freelance science writer in Berlin, wrote the cover story on burnout in the June/July issue of *Scientific American Mind*.

Retrograde Communication

At a typical synapse, the knob at the end of a neuron secretes neurotransmitters such as glutamate (green). These neurotransmitters diffuse across the gap to receptors on a neighboring neuron. The endocannabinoids work in reverse. They are produced in the

postsynaptic cell's membrane, then exit and dock at the knob's CB1 receptors. When docking occurs, that tells the presynaptic cell to stop releasing glutamate. The endocannabinoids, acting as neuromodulators, may protect neurons from overarousal.



mine-producing neurons, helping to fight Parkinson's in its early stages.

Zimmer concurs that the endocannabinoids' primary purpose is to help protect the mental organism from stress. He says, "They protect nerve cells not just from overarousal, but also, for example, from the harmful effects of stress hormones such as cortisol." Lutz adds that cannabinoids also "put the body into recovery mode"; muscles slacken, pulse and blood pressure go down, and mental activity is lessened—all signs of relaxation.

Experts are starting to explain various psychological effects as well. They have trained rodents to fear certain stimuli, then retrained them to subsequently learn that the stimuli are no lon-

ger a threat, gradually extinguishing the fear. Rodents with missing or blocked CB1 receptors, however, do not lose their fear. The endocannabinoids, it seems, are crucial to diminishing bad feelings, and a faulty system might be a prime contributor to post-traumatic stress syndrome or phobias.

Cravings Killer

That a whole lot of things happen when you flood your brain with THC is old news for marijuana smokers, but the effects have suddenly piqued the interest of the pharmaceutical industry.

The pharmaceutical company Sanofi-Aventis, based in Paris, has developed a new drug

called Acomplia, which is already in trials. Its active ingredient, rimonabant, blocks CB1 receptors and is thus supposed to help overweight people shed pounds. “Cannabinoids arouse one’s appetite, apparently through the reward system,” Zimmer explains. Because rimonabant binds to the sites normally used by endocannabinoids, it may be able to stop cravings for food. The principle seems to work, according to results of a company study of 3,000 U.S. and Canadian volunteers, which Sanofi-Aventis released in February. Participants who took the CB1 blocker each day lost more weight than a control group given a placebo. In addition, markers in standard blood

Second, possible side effects related to sustained alteration of the CB1 receptors are unknown and cannot be ruled out. “We have almost no idea what will happen if we inhibit the endogenous cannabinoid system over the long term,” Zimmer says of the brain’s natural reward mechanisms. His perspective comes from his latest experiments with genetically altered mice. When they were young, the mice did markedly better than their unaltered peers in various learning tests. But at the age of three to five months—the prime of life—the mice without CB1 receptors were learning almost as poorly as normal mice at 18 months old, which is elderly. Studies

No one anticipated what has proved to be an entirely new communication system in the brain.

tests that indicate a high risk of stroke or heart attack were lower.

How much of the advantage comes from affecting signals among neurons is not clear, however, in Lutz’s opinion. He ascribes the positive metabolic effects at least partially to the drug’s effect on peripheral organs, which harbor CB1 receptors, too. “In the obese, the endocannabinoid system is overactive in the liver,” he says. “Rimonabant seems to restore it to equilibrium.”

Of course, eating is not the only activity that triggers the brain’s reward system. Many addictive substances do so as well; nicotine prompts the secretion of more dopamine, providing users with satisfied, euphoric feelings. Blocking the endocannabinoid receptors could negate the increased secretion of dopamine, reducing the pleasant feelings that make smokers reach for another cigarette.

Long-Term Concerns

Despite some possible benefits, experts are still wary about tinkering with our natural marijuana network. “The brain is a sensitive system based on inhibitory and excitatory influences, and the endocannabinoids keep this system in balance,” Lutz notes.

One fundamental complication is that, like marijuana itself, man-made versions of endocannabinoids do not simply travel only to desired sites. They spread throughout the brain when taken, causing multiple effects, including dizziness, drowsiness, and concentration and thinking problems.

of the pothead mice revealed they had suffered damage to the hippocampus, the central switchboard for storing memories. The mice that possessed no receptors for their endogenous cannabinoids lost significantly more neurons in the hippocampus than the regular mice did.

This premature cell death, Zimmer believes, could be caused by the loss of the neuroprotective effects of the endocannabinoids. “We must move very carefully to make sure that deliberate medical inhibition of the CB1 receptors does not lead to such damage,” he says, adding that appropriate long-term trials must be held before drugs are released for clinical use in human patients. The pharmaceutical industry may have a different point of view, however; companies such as Sanofi-Aventis hope to bring products to the market soon.

Drug sales aside, the unraveling of the endocannabinoid system is exciting neuroscientists. No one anticipated what has proved to be an entirely new communication system in the brain. Further research will outline the complete mechanisms and could provide novel treatments for a wide range of psychiatric conditions and brain illnesses. **M**

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ANTHONY REDPATH Corbis

Some otherwise healthy people faint at the sight of blood, or if they stand in one place too long. Why?

By Rolf R. Diehl

Feeling FAINT

As soon as her instructor's dissecting knife cuts into the cadaver's skin, a medical student swoons, falling to the floor. Her fellow students pity her, thinking that she is simply too tenderhearted to be a doctor. They are wrong: her problem is not in her head.

Rather than being unable to endure life's occasional unpleasantness, otherwise healthy people who faint when they see a few drops of blood or if they stand in place too long are survivors. They are displaying a lifesaving mechanism bestowed on them by evolution.

For a long time, doctors viewed this behavior as entirely psychogenic—emotionally induced. In such cases, no organic cause presents itself: the electroencephalogram (EEG) looks normal; pulse rate and blood pressure are slightly raised; the electrocardiogram (ECG) shows the heart is working as it should.

But recent research shows that not all such fainting has a psychological basis. Perhaps 10 percent of people have blacked out at least once at the sight of blood, and another 25 percent have suffered the same fate at one time in their lives from standing in place too long. In such cases, the victim's pulse is slow and weak and may be hard to detect at all. Blood pressure is extremely low, sometimes falling below the detection range

of a measurement device; only rarely are the readings higher than 60 over 30 millimeters of mercury. (Normal levels are about 120 over 80 mm Hg.) When the patient regains consciousness, blood pressure and heartbeat quickly return to normal. A few minutes later he or she can usually stand again and feels more or less all right. The patient gives all the indications of having had a temporary, albeit severe, circulatory collapse; the medical term for such episodes is syncope. Such losses of consciousness clearly result from physical processes—and they seem to be systems that make sense from an evolutionary perspective.

Anatomy of a Faint

Only in the past few years have doctors learned that the roots of syncope are in the autonomic nervous system, which is devoted to the control of our inner organs. This system, also known as the vegetative nervous system, generally carries out its functions automatically, and we are not conscious of its operation. It regulates our inner organs

(The Author)

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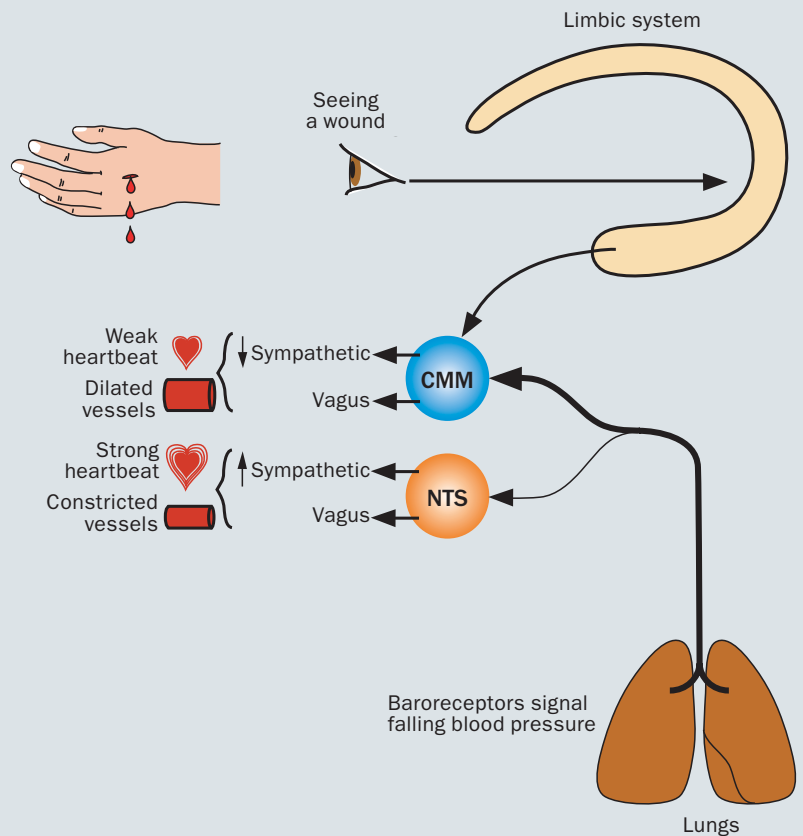
The Body's Toggle Switch

Two different circulatory centers are in the extension of the spinal cord called the medulla oblongata. The nucleus tractus solitarii, or NTS, balances the activity of the vagus nerve and sympathetic nervous system so that blood pressure in the arteries remains nearly constant at about 120 over 80 millimeters of mercury.

The nucleus is continuously informed by the body's blood pressure sensors: the baroreceptors located in major arteries. When they sense blood volume in the lungs dropping—whether as a result of standing still too long or serious bleeding—the NTS can temporarily hold blood pressure steady in the rest of the body. To accomplish this stabilization, it inhibits the vagus nerve and activates the sympathetic system. This action increases heartbeat and causes blood vessels to narrow, raising blood pressure.

The other circulatory center—the caudal midline medulla (CMM)—is also continually updated about blood pressure in the lungs. If the pressure drops too low (the critical level corresponds to a loss of about one and a half liters), the CMM inhibits the sympathetic and activates the vagus. This process slows heartbeat and greatly dilates blood vessels. As a result of this so-called vasovagal reaction, blood pressure drops significantly, and blood flow loss from an injury is stemmed. In humans this reaction can occur not only

when a person has been wounded but when he or she has merely seen blood; in such cases, the CMM is probably stimulated by the limbic system, the area of the brain responsible for emotional processing. —R.R.D.



through two groups of nerves—one originating in the brain stem (the parasympathetic system), the other in the spinal cord (the sympathetic).

The vagus nerve of the parasympathetic, among other activities, slows the heartbeat and relaxes blood vessels, reducing blood delivery through the body. Its counterpart, the sympathetic, makes the heart muscle pump harder and faster, increasing blood pressure and the amount of blood supplied to the organs. In addition, the sympathetic system constricts smaller arteries, raising blood pressure further.

A victim will topple over when the parasympathetic orders a slower heartbeat, reducing blood flow to the organs. Researchers call this form of fainting vasovagal syncope: a loss of consciousness (syncope) in which the blood vessels (“vasa,” from the Latin) are widened and in which the vagus nerve inhibits the heart’s actions.

The parasympathetic system and the vagus nerve are controlled by the brain stem or, to be more precise, by the circulatory centers [see box above] in the medulla oblongata, the part of the brain that extends from the back of the head into the spine. One of these centers—the caudal midline medulla (CMM)—is believed to be responsible for vasovagal syncope, because it is able to arouse the vagus nerve strongly, inhibiting the sympathetic system to a degree that can decrease circulation to a low ebb. In animal tests, researchers determined that the vagus nerve is strongly activated in such “blood-induced” fainting, which would explain both the slowed pulse and the virtual stopping of the heart. The resulting unconsciousness was very similar to human fainting—the pulse, for example, was barely detectable and blood pressure was extremely low.

The CMM always activates when an animal

loses at least 30 to 40 percent of its blood supply (equivalent to about one and a half to two liters in humans) and blood pressure in the chest falls rapidly. How does the circulatory center get this information? To answer this question, it helps to examine the events taking place after such a massive blood loss. First, to ensure that blood continues to nourish the heart and other vital organs,

ing further bleeding. Because of the advantage of having such an emergency survival assist, the feature was conserved over the course of evolution.

But what about fainting at the mere sight of blood? Here, too, an injury is involved—although it is to someone else. When an observer sees the blood, the visual input of the event is thought to go from the brain's visual processors to the emo-

(But now for the really interesting question about fainting: What good is the **resulting blackout?**)

the body redirects blood out of the large veins near the heart and pulmonary vessels. That shift can quickly make up to an extra liter of blood available, which will, at least for a time, keep pressure up in the coronary arteries.

But as the vessels in the chest continue to empty, and the blood pressure falls rapidly, low-pressure baroreceptors—special blood pressure sensors in the coronary and pulmonary arteries—report this drop to the brain stem. When the level dips below a certain critical value, the CMM signals a circulatory collapse.

An Upside to Falling Down

But now for the really interesting question: What good is the resulting blackout? Wouldn't a mechanism that shuts down a circulatory system that is already weakened by massive blood loss cause even more damage? A 2001 study led by Ian Roberts, now at the London School of Hygiene and Tropical Medicine, may provide the answer. Roberts reviewed survival statistics for accident victims who received different treatments. He found that the previously accepted practice of immediately giving people who have suffered serious internal injuries large transfusions for blood replacement often caused more harm than good.

Roberts had an enlightening explanation for this discovery: the transfusions caused the blood pressure in the injured vessels to rise. As a result, more blood flowed out through the wounds. That flow hindered clotting, so that no barriers to ongoing blood loss could form. He concluded that artificially inducing higher blood pressure with an infusion can disturb the body's natural abilities to reduce blood loss.

A general circulatory collapse ordered by the brain may, therefore, be the body's last-ditch effort to recover after a massive blood loss by halt-

tion evaluating center in the limbic system, and from there it is relayed to the CMM. The unfortunate person keels over.

Perhaps this type of fainting results from the CMM's attempt to invoke the vasovagal mechanism even in instances of minor wounds. After all, one's chances of survival often would be improved if clotting began before serious bleeding could occur. To accomplish that benefit, the body's protective reaction would have to take place when the brain perceives the first visible evidence of injury. The side effect is that the lower the trigger point is set for the vasovagal circulatory collapse mechanism, the higher the chances of a false alarm, such as fainting at the mere sight of blood—even if it is from another person.

And how about people who collapse after standing in a stationary position for too long? Their bodies are reacting to a similar signal of a blood shortfall, but the cause is different: gravity. As a person stands stock-still, about half a liter of blood can be pulled into veins in the legs. Because gravity constantly presses liquid out of the capillaries in the legs and into surrounding tissue, the blood volume can continue to decline. Ultimately, blood pressure in the chest can drop below the trigger point, and the CMM in the brain stem will order a circulatory collapse.

As science has demonstrated, a person who faints when he sees a wound or stands at attention is not displaying physical frailty but rather a successful (if hair-trigger) survival edge. Maybe it is time to alert the dictionary editors. **M**

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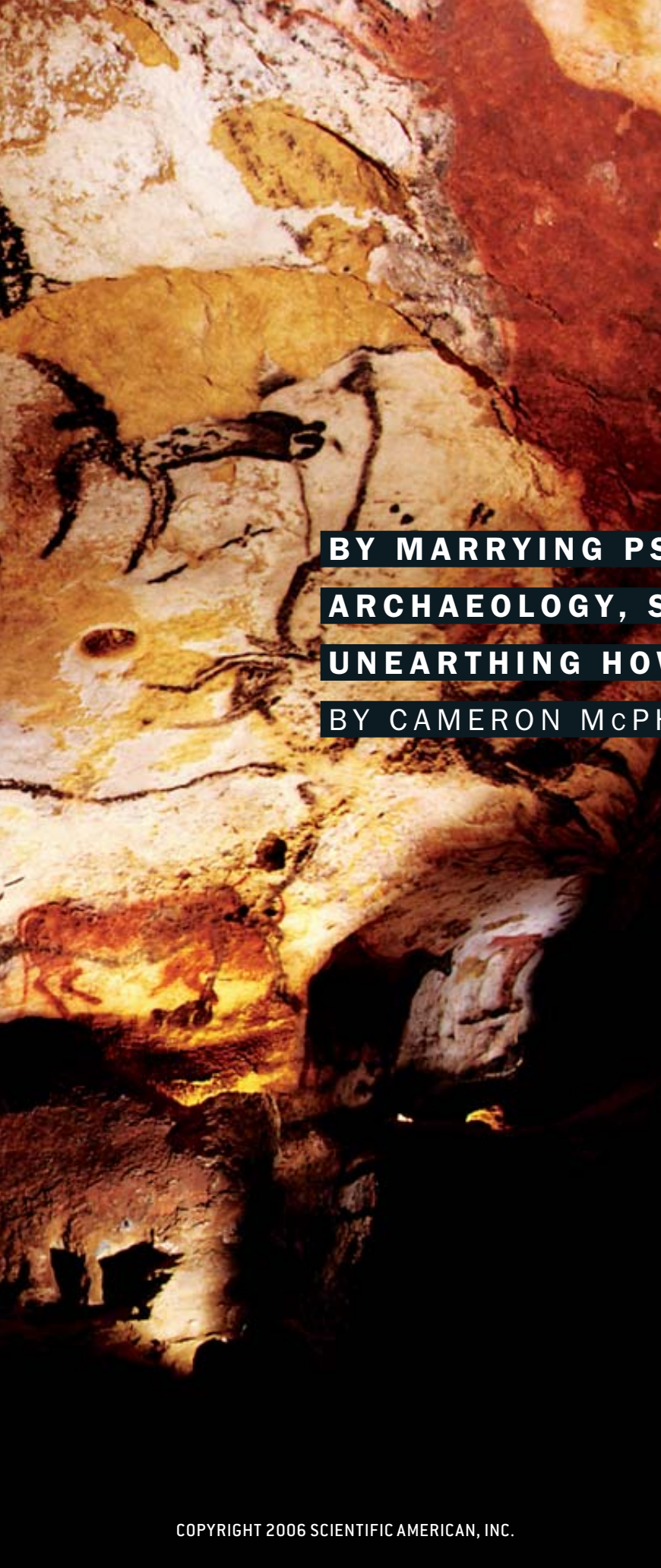
RISE

of the

MODERN

MIND

Animals painted 17,000 years ago
crowd cave walls in Lascaux, France.



**BY MARRYING PSYCHOLOGY WITH
ARCHAEOLOGY, SCIENTISTS ARE
UNEARTHING HOW THOUGHT EVOLVED
BY CAMERON McPHERSON SMITH**

As an undergraduate at the University of London's Institute of Archaeology, I was taught that archaeology was ultimately about "the mind behind the artifact." It was about the person who made the ancient object I happened to be studying. That perspective seemed easy enough when I contemplated the simple chipped stones that represent most of human prehistory. The minds responsible for those artifacts, I naively thought, must have been pretty simple. But when my studies advanced to the explosion of cave art, burial relics and complex tools that signaled the appearance of modern humans more than 30,000 years ago, I just could not understand how that new mind had come to be. What could account for the radical cognitive bloom? So I asked an instructor. His cheerful, rhetorical response was quintessentially British: "They became very smart?"

Humanity certainly did become very smart, and we know roughly when and where, because the transition from the utilitarian tools of early humans to the rich splendors of modern humans is clear in the archaeological record. But for a long time, *how* the modern mind evolved—what it meant to become “very smart”—was a problem too big to tackle.

Not anymore. Although Charles Darwin conclusively demonstrated a century and a half ago that the physical brain had evolved, only recently have we been able to say with certainty that the mind—what the brain does—evolved as well. This evolution is being examined by a new discipline called cognitive archaeology. Wielding the tools of psychology and archaeology, cognitive archaeologists interpret artifacts in terms of what they tell us about the minds that made them, for example, by estimating the mental “age” required to make a stone tool or determining how the symbolic complexity of an artifact indicates a certain level of consciousness. And by applying the concept of evolution to the mind itself, cognitive archaeologists are unpacking the vague concept of becoming very smart, revealing intriguing insights about what went on in our ancestors’ heads throughout human prehistory.

That, in turn, raises some interesting questions about what is going on in our minds now and why.

EPISODIC CONSCIOUSNESS
The early human mind, which reigned from about four to two million years ago, used simple tools only in the moment, discovering them again and again. The asymmetry of this “end chopper” from Olduvai Gorge in Tanzania shows little deliberate design.



Representing Reality

Evolution is characterized by change, so an evolutionary investigation into the modern mind begins with a deceptively simple question: What changed in the mind, through time?

Canadian psychologist Merlin Donald presented the first comprehensive attempt at an answer in his trailblazing 1991 book, *Origins of the Modern Mind*. His model was so influential that it shaped the pursuit of cognitive archaeology, including now annual conferences as well as the *Cambridge Archaeological Journal*, dedicated in 2000 to cognitive and symbolic archaeology. Cross-disciplinary research has also sprung up; Liane Gabora, assistant professor of psychology and computer science at the University of British Columbia, has been influenced by Donald’s concepts in her investigations of the evolution of cultural innovation and creativity.

Donald proposed that the evolution of the mind was fundamentally about the ways it represented its experiences. His model—supported by a diverse body of archaeological and psychological data—outlines several revolutions in how the mind managed the information stored in the brain, with each change yielding a new level of cognition, a new state of consciousness.

Donald, now chair of cognitive science at Case Western Reserve University, begins his account more than four million years ago, with the minds of our African protohuman ancestors. Based on their limited use of asymmetrical, often found, objects as tools and other evidence, he likens their minds to those of modern chimpanzees. Chimps are excellent at perceiving the immediate significance of events, but they do not retain most of those events in long-term memory, nor do they think abstractly about what the events might mean in the far future. When taught sign language, for example, chimps use it for immediate concerns, like requests for treats. Donald calls this ability “episodic consciousness,” a bubble of short-term, small-space awareness.

The first cognitive revolution took place with the appearance of early humans (early *Homo*) around two million years ago. Their symmetrical stone tools indicate a fundamentally new mind that possessed the capacity for voluntary representation. The symmetrical shapes were not produced because of a utilitarian need for that symmetry but because the mind was specifically recalling a concept of “this is how we make tools,” and individuals represented that concept, via the tool itself, to peers. Rather than recalling experiences only in an automatic, reactive way, this

SISSE BRIMBERG National Geographic/Getty Images (preceding pages); NATIONAL MUSEUM OF TANZANIA, DAR ES SALAAM; © 1985 DAVID L. BRILL (this page)

mind could proactively select a past experience and convey it to others, by making a tool in the “appropriate” shape and using that tool in the presence of others in society. Furthermore, a group of individuals that hewed to symmetry and used symmetrical tools publicly promulgated the concept of group unity; unity was signaled by the symmetrical “style” of the tool architecture.

Communicating intentionally retrieved memories would have required some kind of representational act, and language immediately comes to mind. But Donald suggests a precursor, called mimesis—communication based largely on symbolic gesture and simple vocalizations. According to Donald, culture and tools were complex enough that teaching them to a young hominid required high-fidelity communication of ideas. Because no artifacts showing fully developed symbolism (such as simple drawings) exist from this period, however, Donald is left to conclude that an individual transmitted information with body gestures and prelinguistic vocalizations. Such mimes and sounds might even have been strung together in sequences, acted out and rhythmically organized.



MIMETIC CONSCIOUSNESS
Two million years ago early *Homo* began making tools with a specific, symmetric shape. Tribal members shared an “appropriate” architectural style, exemplified by this 1.8-million-year-old hand ax from Olduvai Gorge.

(Cognitive archaeology will be a great aid to understanding why we think the way we do.)

NATIONAL MUSEUM OF TANZANIA, DAR ES SALAAM; © 1985 DAVID L. BRILL

Although we do not yet know just how mimesis arose, it had the profound effect of bursting the bubble of episodic consciousness. It allowed contemplation of the past and future, along with abstraction—the ability to develop a concept that stands for a concrete object or event. As mimetically represented acts became more complex, standardized and abstracted (for example, gestures that no longer resembled the subject they represented, such as fear or anger), a need arose for organizing the clutter of symbols. The first scheme was probably some kind of mental dictionary that told early hominids that mime A meant B, and so on.

A second, more important solution then appeared: lexical invention, which occurred around 300,000 years ago but fully blossomed in modern humans after 150,000 years ago. The heart of lexical invention was the innovation of symbols far richer than the literal metaphors of mimesis, evident in the earliest traces of symbolic artifacts. These examples include the 75,000-year-old drilled shells (probably strung on neck-

laces) and engraved stones from Blombos Cave in South Africa.

How did lexical invention happen? How did our ancestors increase the richness of their symbols? Donald’s answer is as fascinating as it is counterintuitive. It happened not by clearly defining what symbols meant but by making them “fuzzier”: by allowing a given symbol to take on a different significance depending on its context. A symbol for “snake” could now be used to indicate a winding river or even the characteristics of a person. In this way, language facilitated the communication of ever more intricate thoughts. Speech arose as a subsystem of mimesis, a more efficient way to represent increasingly complex sets of voluntarily recalled memories.

Just as mimesis broke the mind from episodic consciousness, lexical invention expanded the mind from the rather literal world of mimetic consciousness. Mimesis provided a conceptual dictionary; lexical invention provided a conceptual thesaurus.

The linking of ideas through lexical invention

Painting narratives on cave walls moved memories outside the body onto external storage media.

MYTHIC CONSCIOUSNESS
Language spawned a riot of ideas that needed to be organized. Myths, told through cave drawings such as this 15,000-year-old horse surrounded by symbols, from Lascaux, France, were the solution.



had a breathtaking snowball effect, and the resulting complexity, Donald suggests, cried out for organization. That need spawned the development of myths: narratives that integrated and organized the riot of ideas. These probably began as simplistic, morally guiding dramas, populated by gods, villains and heroes, and grew into the elaborate yarns we still tell today. Mythic consciousness integrated memories into specific narratives that were told and retold as cultural models of what the universe was like and what to do about it. Archaeologically, mythical consciousness is evidenced by the appearance of cave art more than 30,000 years ago, which evolved into paintings that depict ancient myths, complete with fantastic creatures, abstract designs, human-animal

hybrids, and more. French prehistorian Jean Clottes has recently applied cognitive archaeology to the spectacular cave art of Europe, interpreting some of the depictions as mythical scenes and others as recollections of shamanic voyages in which ancient healers “traveled” to the spirit world to solve problems people were having in the material world, such as poor health.

I think of myths as encyclopedic. The mimetic dictionary indicated that A specifically meant B. The lexical thesaurus expanded meaning by saying that A could mean B or C or D, depending on circumstances. The mythic encyclopedia organized A, B, C and D into narratives that conveyed and cross-referenced the contents of the mind.

As that mind became crowded with rich mythic stories representing enormous bodies of knowledge, yet another new system arose to organize and store that knowledge. This solution was technical, not biological. The idea was to off-load some of the brain’s information-management demands to the outside world. Painting narratives on cave walls or cutting notches into tablets of bone—each as a record of some event—had the profound effect of moving memories out-

(The Author)

CAMERON McPHERSON SMITH is an archaeologist at Portland State University. Educated in England, Canada, Africa and the U.S., he has practiced the archaeology of all periods from early human to modern civilization. His courses emphasize the principles that have structured the evolution of the human body, culture and mind. His book, *The Top Ten Myths about Evolution*, will be released by Prometheus Books this autumn.

ROBERT HARDING Getty Images

side the body, onto external memory storage media. Information was no longer limited by what people could physically remember. External memory allowed for the storage and recall of an infinite amount of information.

Human refinement of cave paintings, hieroglyphs, alphabets and more led to what Donald calls theoretical consciousness. These recordings, particularly writing (which first appeared around 6,000 years ago), freed information from context. Unlike oral myths or cave paintings—which could be understood only in their own cultural context—abstracted writing systems allowed information to be understood regardless of its cultural context. Now information could be contemplated in completely abstract terms.

Theoretical consciousness puts a premium on skills that manage information and integrate thought rather than on rote memorization. Intelligence—a property of the mind that resides in the brain—is about innovation, which results from novel associations of ideas found in huge bodies of information. It is astounding to realize today how much information is stored outside the brain, for example, in libraries or on the Internet.

Echoes in Consciousness

Donald's hierarchy of episodic, mimetic, mythic and theoretical consciousness handily explains what changed in the mind across human evolution. Each new step did not steamroll the previous one, however. Rather new consciousnesses were superimposed on the old. We rely almost completely on episodic consciousness when we are intensely engaged in a single task, such as leaping from a diving board or steering a car across an icy road. We invoke the nonvocal communication of mimesis when we fold our arms and scowl at a rude child or dance across a stage, conveying joy.

Mythic consciousness continues to shape how we think. In personal letters, long novels and international nuclear-nonproliferation meetings, we use language to tell our stories, negotiate their content to agreeable truths, and proceed with our objectives. And on any given day, theoretical consciousness allows us to contemplate grand problems such as the physics of relativity.

The modern mind switches from one variety of consciousness to another as easily as changing television channels. And we constantly sift through our experiences, combining new ones with representations of old ones retrieved from all manner of biological and external memory stores, to fashion new worlds of meaning and layer on



layer of metaphor. For Donald, the hallmark of the modern mind is this constant integration and reintegration of experiences via multiple, innovative means of representing information.

Cognitive Fluidity

But how has the modern mind evolved to forge productive links between ideas? One answer comes from an alternative model of the evolution of consciousness being explored by British cognitive archaeologist Steven Mithen, head of human and environmental science at the University of Reading. For Mithen, the key variable that has structured the evolution of the modern mind is cognitive fluidity—the degree to which different kinds of intelligence communicate with one another. Unlike Donald's model, which focuses on the evolution of modes of representation, Mithen's theory focuses on the well-established observation that the human mind is composed of "modular" domains of intelligence. He explains the mind's evolution as an increasing level of interaction among these domains.

Mithen identifies four main types of intelligence: linguistic (production and comprehension of language), social (managing interpersonal relationships), technical (manipulation of objects), and natural history (understanding cause and effect in the natural world). The modern human mind, Mithen argues, is the only one in which there is free communication among these domains.



THEORETICAL CONSCIOUSNESS
Writing, which appeared around 6,000 years ago, allowed information to be contemplated abstractly. An early example is a Sumerian clay tablet with cuneiform characters that tallies sheep and goats, from Tello in ancient southern Mesopotamia. Writing later took higher forms, such as the solar system chart by Copernicus (top).

**COGNITIVE
FLUIDITY**

One theory says the modern mind sprung up 50,000 years ago, when language opened doors between the brain's previously isolated domains of intelligence. This 32,000-year-old "lion person" figurine from Hohlenstein-Stadel Cave in Germany shows a fluid connection among social (human), natural history (animals), and technical (made objects) domains.



By four million years ago, Mithen argues, our African protohuman ancestors possessed a well-developed social intelligence, as expected in groups of large social primates. But by two million years ago—for reasons paleoanthropologists still have not comprehensively explained—a significant change occurred in hominid life. Early humans, including *Homo habilis*, began using stone tools to butcher carcasses scavenged from big-cat kill sites. This activity did not represent cognitive fluidity yet, although it significantly sharpened early hominid technical intelligence (making tools) and natural-history intelligence (finding carcasses). It was also the first sign that creativity and intelligence would be the ace in the hole for the relatively fragile, lightly built *Homo* lineage; from this point on, *Homo* would rely on brains, not brawn.

The early human mind, Mithen maintains, comprised three of the four domains of intelligence that form the modern human mind (the missing one being language). But significantly, they remained isolated from one another. Mithen's metaphor for the early human mind is that of a cathedral, composed of separate, walled-off compartments, each used for special purposes. In the early human mind, there were no doors

connecting the compartments, no communication between the domains of intelligence.

This cognitive isolation lasted for the vast period occupied by middle humans, including *H. erectus*, a species so strange that in my lectures I refer to it as "bizarre." What is strange is that, although the mind of *H. erectus* drove the body to make sophisticated, symmetrical stone tools that could be fashioned in 15 minutes, *H. erectus* used those tools for more than a million years without ever really innovating a new design. Middle humans were smart, but there is no sign of the continuous technical innovation characteristic of the modern human mind. Many well-defined and dated artifacts show that from about two million years ago to about 300,000 years ago, middle humans thought about making a stone tool (technical intelligence) yet did not simultaneously think about the specific animal they would butcher with that tool (natural-history intelligence). The two intelligences remained compartmentalized. Archaeologist Clive Gamble of Royal Holloway, University of London, has described the society built by these minds as a 15-minute culture, characterized by routinized actions.

The apparent mental stasis of the middle humans is interrupted by a few innovations crafted by one of their late offshoots, the Neandertals, who flourished in Europe and the Near East after 200,000 years ago. Neandertals' intelligence was largely technical, but they did use a kind of mimetic symbolism, as well as some rudimentary language, and may have even contemplated an afterlife, as suggested by a few burial sites. Still, like *H. erectus*, what is most striking is what Neandertals did not do. For example, the few burial sites do not contain "grave goods" for a voyage into an afterlife, suggesting that Donald's mythic narratives (ostensibly necessary to sustain such a belief) simply did not exist. Life and death, it seems, were pretty much literal.

Quoting Tufts University philosopher Daniel Dennett, Mithen characterizes the Neandertal mind as "rolling consciousness with swift memory loss." By about 30,000 years ago that variety of consciousness became extinct, with the Neandertals themselves, who had been replaced by modern humans who emerged from Africa and took over the Neandertals' geographic range. For Mithen, the most important characteristic of this new wave of humans was a mind capable of cognitive fluidity—opening doors between compartments in the cathedral.

The rich, fluid communication between modules of intelligence began only in the past 200,000

years, and the key that unlocked the doors was language. According to Mithen, early language arose as social groups became larger and more complex. Bits of information about various aspects of life began to slip into what had started as utilitarian spoken communication (perhaps because of Donald's lexical invention). For example, information from the domain of natural-history activities began to slip into the domain of social activities. The resulting cross-referencing led to vast new realms of thought.

Imagine thinking not just about social, technical and natural-history domains separately but

cause Barney is "inappropriately" mixing information from the technical domain (the car) and the social domain (the feeling of pain).

Certain cognitive disorders also appear to be rooted in a lack of fluidity. Autistic persons and savants can be brilliant in a certain domain, such as being able to recite every word of a novel, but they typically have very routinized, channeled ways of thinking and behaving that do not allow for cross-fertilization of ideas.

We have one mind, but cognitive archaeologists currently have two different models for it. For Merlin Donald, the modern mind evolved as

(For a million years there was **no sign** of the continuous innovation that characterizes the modern mind.)

about all of them at the same time—say, about people, objects made by human hands, and lions simultaneously. Only this kind of cognitive fluidity, Mithen asserts, could account for the explosion of rich symbolism associated with modern humans, such as the lion-person figurine found at Hohlenstein-Stadel Cave in Germany, dated to 32,000 years ago [see illustration on opposite page]. For Mithen, the lion-person is a physical manifestation of cognitive fluidity. Numerous excavations show that such rich symbols are glaringly absent until modern humans emerge from Africa after 50,000 years ago.

Because modern humans rely on inventions (rather than on biological adaptations) to survive, innovation is humanity's ace in the hole, and it is facilitated by cognitive fluidity, rooted in language. Ultimately, integrated thought replaced (or at least complemented) compartmentalized thought, inventing the concepts and tools that have, for better or worse, brought us to where we are today.

One Mind, Two Models?

In the same way that echoes of early and middle human consciousness are heard in the mimesis and mythic narratives we still use today, Mithen suggests that our modern minds also exhibit artifacts of the ancient isolation of cathedral chambers. Humor, he points out, often arises from an "inappropriate" crossing of domains of intelligence. When Don Knotts, playing the bumbling deputy sheriff Barney Fife, cringes as the door of his precious new car is slammed shut—as though he himself were being hit—we laugh not because the car is being hurt but be-

novel modes of recalling and representing information evolved. For Steven Mithen, the modern mind evolved as a consequence of communication between previously isolated modules of intelligence. Can these two explanations be reconciled?

According to Donald and Mithen themselves, the answer is both yes and no. The two thinkers have favorably reviewed each other's work, albeit with provisos. Mithen embraces Donald's evolutionary approach to the mind but wrote his own 1996 book, *The Prehistory of the Mind*, in part to address what he considers Donald's incomplete use of the potential of the archaeological record. And Donald has called Mithen's approach worthwhile, although he suggests that Mithen underestimates the significance of representation. For the moment, the jury is out. Many experts are now fine-tuning models describing the evolution of mind, yet they are all arguably guided by Donald's and Mithen's principles.

What is most exciting is that there is no going back now. We know that like the physical brain, the mind evolved, too. Getting closer to our ancestors—closer to the minds that created the artifacts—requires us to apply everything we know about evolution to the study of consciousness itself. Ultimately, cognitive archaeology will be an enormous aid to understanding who we are and why we think the way we do. **M**

(Further Reading)

- ◆ **Origins of the Modern Mind: Three Stages in the Evolution of Culture and Cognition.** Merlin Donald. Harvard University Press, 1991.
- ◆ **The Prehistory of the Mind: The Cognitive Origins of Art, Religion and Science.** Steven Mithen. Thames and Hudson, 1996.

Fostering Group Creativity

The right atmosphere, and a few gimmicks, can bring out bright ideas among any collection of people

BY JOERG MEHLHORN

IN THE PAST FEW YEARS, much has been written about ways to foster creativity in individuals. But groups of people—at the office, in church committees, among volunteer organizations—may need just as much help finding a collective spark. Here are some tricks, beginning with a word of caution.

Forbid criticism. No group will generate brilliant insights if participants are hostile to crazy ideas. Collective imagination can flourish only if everyone feels free of anxiety and full of trust. Before brainstorming begins, a group must insist that no one can criticize anyone who throws out an idea, makes a mistake, or lets his or her imagination run wild. Comments such as “That makes no sense!” poison a creative environment.

Indeed, one of the ground rules set by facilitators who run professional brainstorming sessions is expressly to forbid criticism. Meetings convened to come up with new concepts fail as

soon as participants begin to pass judgment or prematurely discard ideas. By banning criticism, a group creates a space that even the most reticent members will recognize as safe to suggest half-baked ramblings. Ideally, a brainstorming session should have two phases, separated in time and composed of different participants: people in the creative session would be responsible for coming up with ideas, and a second group would apply critical analysis to separate wheat from chaff.

Hide the problem. Most brainstorming techniques advise that group size be five to seven participants, each of whom has a different expertise, and that sessions last at least 30 minutes. An interesting variation on the straightforward swapping of ideas is called didactic brainstorming, in which the problem is known only to a moderator. He or she starts the group’s exercise by setting a much broader topic for discussion and then, over the course of

the session, narrows the topic, getting closer to the real issue. For example, a session could begin with the general question “What do we find attractive?” even though the final goal is to fashion new packaging for a food item.

The advantage of this technique is that participants do not immediately focus on the obvious suspects—the relatively small number of ways to package foods that people see every day in stores. Obscuring the problem allows unusual twists to arise from different perspectives.

Hand off partial solutions. Another variety of brainstorming is called brainwriting. Six participants each receive a piece of paper with 18 blank boxes, arranged in three columns of six squares. Each column represents one aspect of the problem—for packaging, perhaps “attractiveness,” “novelty” and “cost.” Each person is told to jot down one idea in the top box of each column. After about five minutes, each “player” passes his or her sheet to the person on the left. This person must use the second box to develop or elaborate on the point made in the preceding box. And so on. In the best possible world, 108 ideas will result in half an hour (six pages of 18 boxes).

“Brainwalking” is a different form of the same exercise. Two or three people gather in front of a flipchart or a big page posted on the wall that represents one aspect of the problem. Several pages, one for each aspect, are spread around a room, each with several people ready to tackle them. Members of each small group spontaneously write down every idea on that topic that pops into their head. Then the groups move to the next chart, where they will see the notes left by their colleagues and add new associations. As the exercise proceeds, concepts grow step by step and often branch out in unexpected



In “brainwalking,” small groups move from poster to poster and enlarge on the ideas of the prior participants.

ANDREAS RZADKOWSKY Gehirn & Geist

Banning criticism will encourage **even the most reticent** group members to suggest half-baked ramblings.

ed directions. An additional advantage is that physically moving around stimulates thinking.

Induce intuition. Sometimes it can pay to put the cart before the horse—such as when the goal is conjuring up a new product. Start by proposing product names and only then try to imagine a worthwhile innovation. This method is called semantic intuition. Say the goal is to conceive a kitchen gadget. Create a list of concepts taken from cooking and eating (pan, lid, jar, plate, grill). Now join the words in every possible combination. You might just discover a term, such as lid grater, that could become a novel product: a jar with a grater in its lid, for making fresh nutmeg.

Force different points of view. The basic principle of separating the conception of ideas from their evaluation has been embraced and promoted for 30 years by well-known creativity expert Edward de Bono of Oxford, England. His “six thinking hats” game is widely used to help groups generate ideas yet also critique them.

Five people, say, gather in a room. There are six sets of (five) hats on a table. Each set is a different color, which represents a different perspective. A problem is announced, then the five players put on the five hats of one color and discuss the problem only from that point of view. The white hat represents facts and figures. The red hat stands for intuition, feelings and emotions. The black hat is for judgment and caution. Yellow looks only at an idea’s advantages. Green is for alternatives and free associations. And blue is to moderate the proceedings.

Once the exercise begins, the group switches hats in any order. Perhaps, after some red hat feeling out, someone will say, “I think we need some white-hat thinking.” The people put on those hats and consult their database or survey results or some such information.



In Edward de Bono’s “six thinking hats” method, the red hats stand for intuition, the green for creativity, the blue for readjustment.

If the process stalls, the group might put on the blue moderator hats to decide what step to take next.

The crucial point is that a given hat focuses the group on one task. It blocks arguments between opponents and proponents of an idea because everyone must look at ideas only from one perspective at a time. Yet as the participants rotate through all the hats, the system allows them to concentrate on an idea’s strong points (yellow) or its disadvantages (black). And they can keep going back to the green hat for fresh inspiration.

Separate roles. It is said that one of the most creative minds of the 20th century worked in a similar way. Walt Disney, famed animator and entertainment giant, was known to assume one of three roles whenever he held meetings about a new project. He could be the dreamer, the realist or the critic, depending on which function he thought, on the spur of the moment, was most needed.

Anyone wishing to play all these roles should physically separate them—for example, by putting a chair in each of three corners of a room. Disney reportedly built a separate room for each role: one was big, bright and attractive for the dreaming; another had the necessary technical equipment for realization; and the third was a narrow little space for ruthless criticism.

Group creativity can be greatly enhanced with the tips mentioned here as well as with other exercises. The key is to separate the needed types of input, so that each stage can proceed unfettered. First, it is necessary to be visionary. Then the visions can be confronted in the light of reality. Then, and only then, should the ideas be opened to criticism. If they are truly creative, they will stand up to rigorous review. **M**

JOERG MEHLHORN is professor of business management and president of the German Association for Creativity in Mainz.

Mistrusted Adviser

A Mind of Its Own: How Your Brain Distorts and Deceives

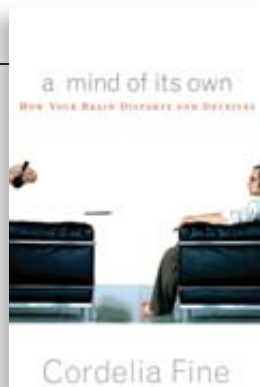
by Cordelia Fine. W. W. Norton, 2006 (\$24.95)

Many psychological studies show that on average, each of us believes we are above average compared with others—more ethical and capable, better drivers, better judges of character, and more attractive. Our weaknesses are, of course, irrelevant. Such self-distortion protects our egos from harm, even when nothing could be further from the truth. Our brains are the trusted advisers we should never trust.

This “distorting prism” of self-knowledge is what Cordelia Fine, a psychologist at the Australian National University, calls our “vain brain.” Fine documents the lengths to which a human brain will go to bias perceptions in the perceiver’s favor. When explaining to ourselves and others why something has gone well or badly, we attrib-

ute success to our own qualities, while shedding responsibility for failure. Our brains bias memory and reason, selectively editing truth to inflict less pain on our fragile selves. They also shield the ego from truth with “retroactive pessimism,” insisting the odds were stacked inevitably toward doom. Alternatively, the brain of “self-handicappers” concocts nonthreatening excuses for failure.

Furthermore, our brains warp perceptions to match emotions. In the extreme, patients with Cotard delusion actually believe they are dead. So “pig-headed” is the brain about protecting its perspective that it defends cherished positions regardless of data. The “secretive” brain unconsciously directs our lives via silent neural equipment that creates the illusion of willfulness. “Never forget,” Fine says, “that your unconscious is smarter



than you, faster than you, and more powerful than you. It may even control you. You will never know all of its secrets.”

So what to do? Begin with self-awareness, Fine says, then manage the distortions as best one can. We owe it to ourselves “to lessen the harmful effects of the

brain’s various shams,” she adds, while admitting that applying this lesson to others is easier than to oneself.

Ironically, one category of persons shows that it is possible to view life through a clearer lens. “Their self-perceptions are more balanced, they assign responsibility for success and failure more even-handedly, and their predictions for the future are more realistic. These people are living testimony to the dangers of self-knowledge,” Fine asserts. “They are the clinically depressed.” Case in point.

—Richard Lipkin

Mind Reads



Unmasking Scoundrels

Cunning

by Don Herzog. Princeton University Press, 2006 (\$24.95)

Perhaps the first question you might ask someone who has just read a book is, “What is it about?” That would be difficult to answer for *Cunning*, even though Don Herzog, a professor at the University of Michigan Law School, spells out his intentions: “Here’s an enticing labyrinth

full of problems, with the paths of morality, roles and rationality crossed, confused, confusing.” What he means is that being cunning—crafty, shifty, sly or even duplicitous—creates psychological dilemmas for both the outsmarted and the outsmarter.

To explore these dilemmas, Herzog revels in myriad stories from a wild range of sources, many old and some obscure—from English witchcraft narratives to Nigerian e-mail scams. “What were these people thinking?” is one big question he asks. “How should we regard them?” is the other.

The book’s first section, “Dilemmas,” considers whether the world is divided into knaves and fools. Greek hero Odysseus—

thoroughly amoral but perhaps more pragmatist than knave—and Italian statesman Machiavelli are the prime subjects of discussion. Making judgments about these scheming men, it seems, is a tricky enterprise.

The second section, “Appearances,” deals with the unmasking of scoundrels—knowing whom, or what, to trust. The O. J. Simpson case is one example in which no party, not even the police, seems worthy of unquestioning trust. At the level of daily life, Herzog wrestles with buying a used car: salespeople, he concludes, have no choice but to be cunning, and we have no choice but to distrust them.

The final section, “Despair,” delves into a fair amount of philosophy—Herzog cites British philosophers Thomas Hobbes and David Hume above all—but is not as focused. It does contain the story of Thérèse Humbert, a French farm girl of the late 19th century who reinvented herself as “an American billionaire’s illegitimate daughter.” Herzog wonders whether Humbert was truly cunning or sincerely self-deluded.

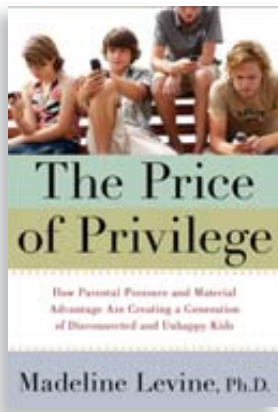
Whether you enjoy *Cunning* or put it down in frustration will depend on your tolerance for Herzog’s cleverness. Does he have anything new to say about Odysseus or the biblical Jacob, or has he merely read the literature on these dubious characters? He flits from sermons preached at executions to the ethics of Amway sales tactics, never tarrying long with any one example. It is hard to say at the end where he has gotten, but it is clear that he, anyway, had fun getting there.

—Jonathan Beard

Land of Empty

The Price of Privilege: How Parental Pressure and Material Advantage Are Creating a Generation of Disconnected and Unhappy Kids

by Madeline Levine. HarperCollins, 2006 (\$24.95)



Wandering among suburban estates, sports clubs and prep schools are overlooked children of a perplexed generation. Their lives overflow with abundance and praise, yet ironically, the mask of apparent health and success may hide a gloomy world of emptiness, anxiety and anger.

Strangely, argues Madeline Levine, a clinical psychologist practicing in Marin County, California, the nation's latest group of at-risk kids comes from affluent, well-educated families. De-

spite advantages, these children experience disproportionately high rates of clinical depression, substance abuse, anxiety, eating disorders and self-destructive (even self-mutilating) behaviors, according to various studies. Based on criteria from the U.S. Centers for Disease Control and Prevention, Levine says these children "are exhibiting epidemic rates of emotional problems beginning in junior high school and accelerating throughout adolescence."

One may brush off these youngsters as overindulged products of wealthy, narcissistic parents. But Levine says many of these kids are really ill. They suffer from a weak sense of self, often struggling to fill inner emptiness with objects and praise. Too often they know something is wrong and grope desperately for help yet fail to escape a downward spiral.

Could it be, Levine wonders, that privilege, high expectations, competitive pressure and parental overinvolvement yield toxic rather than protective effects? Levine explores such issues as social isolation, the fine line between parental underinvolvement and overindulgence, and the perverse role of money and material goods in creating false promises of fulfillment. Yearning for outward approval, adolescents are particularly vulnerable to the delusion that wealth causes happiness. In many cases, a rude awakening occurs only after many years of anxiety and depression.

Levine's writing is surprisingly reflective and interesting. A constructive therapist, she offers practical guidelines and parenting strategies for those struggling with troubled teens. The advice is useful to any parent of any income level and includes ways to foster healthy autonomy, impulse control and sense of self. Levine emphasizes the importance of discipline, monitoring and limit setting as ways to encourage kids to construct healthy "inner" homes. More important, parents must "stand on their own two feet" before expecting their children to stand on theirs—noting that many parents scold their children for social behaviors that they themselves cannot manage, such as substance abuse and lack of self-discipline or self-assertion. Parents must strive to get their own inner homes in order before they can expect kids to straighten out theirs. —Richard Lipkin

Catastrophes of Mind

Fascism and Democracy in the Human Mind: A Bridge between Mind and Society

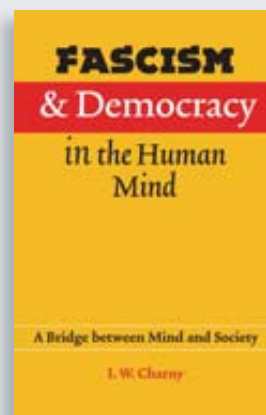
by Israel W. Charny. University of Nebraska Press, 2006 (\$49.95)

Is there any connection between the way individuals think about their lives and relationships and the way societies behave toward their citizens? Israel W. Charny, a psychologist working in Israel who has devoted his practice to family and couples counseling and much of his life to a study of genocide, believes there is. "Fascist-type thinking," he says, leads to destroyed relationships and thwarted lives for individuals and to authoritarianism and genocide at the societal level.

Charny plies his postulate not at the simplistic level of "the Nazis committed genocide because they were crazy" but in the sense that all of us have both "fascist" and "democratic" components to our minds. The fascist programs, which he likens to human software, "tell you what to do with certainty, without questioning or alternative frames of reference....

They instill in you a sense of superiority." In contrast, the programs of the democratic mind invite responsibility for choosing one's direction in life, support questioning and are "accompanied by a readiness to change." He explains why fascist ideas seduce both societies and individuals who crave solutions to life's complexities and why the results are catastrophic for both. Democratic ways of thinking and an openness to other people and new ideas—although they provoke uncertainty and anxiety—are his alternative prescription for individuals and societies that prize humanity.

Once Charny sets out these fairly simple ideas he expands on them by citing a vast array of writers, most of them psychologists, who have discussed the abuse of power to illustrate the consequences of fascist systems—especially when the abuse leads to genocide. And to provide examples of both fascist and democratic behaviors in personal life, he includes scores of case histories from his many decades of work in American and Israeli mental health clinics. The discussion gives him ample opportunity to list his dislikes—Hitler, Stalin, Mao, the Taliban, Prozac and controlling parents—as well as his likes, such as child psychologist Bruno Bettelheim, good sex, psychologist and philosopher Erich Fromm, and the Alexander Technique of self-awareness and body control. He also tells lots of entertaining stories about patients. Unfortunately, the result is a book that is much too long for its message. What could have been a short essay about habits of mind and their personal and political implications swells into a repetitious, often self-serving mixture of the author's opinions and favorite stories. —Jonathan Beard



asktheBrains

Could certain frequencies of electromagnetic waves or radiation interfere with brain function?

—L. Chamas, Montreal



Amir Raz, assistant professor of clinical neuroscience at Columbia University, replies:

DEFINITELY. Radiation is energy, and research provides at least some information concerning the ways in which specific types of energy may influence tissue, including the brain. I will review what we know about several types.

MAGNETIC FIELDS. In some cases, the effect can be therapeutic. For example, transcranial magnetic stimulation (TMS) is a technique used to induce a short-term interruption of normal activity in a relatively restricted area of the brain. Head-mounted wire coils deliver magnetic pulses directly into focal brain regions, painlessly delivering minute electric currents. TMS may be helpful in alleviating certain symptoms, including those of depression.

Also, magnetic resonance imaging (MRI) of the living brain uses an externally imposed magnetic field. Preliminary findings suggest that bipolar-disorder patients' moods improve immediately after they undergo a specific MRI procedure; further investigation is warranted.

IONIZING VS. NONIONIZING RADIATION. Researchers typically differentiate between the effects of ionizing radiation (such as far ultraviolet, x-ray and gamma ray) and nonionizing radiation (including visible light, microwave and radio). The ionizing variety can cause DNA damage and mutations; thus, we should limit exposure to its sources—radioactive materials and sunlight among them. In ionizing radiation, an individual particle or photon carries enough energy to ionize (remove an electron from) an atom or molecule.

The picture for nonionizing radiation is less clear. Extremely low frequency electromagnetic fields (EMF) surround home appliances as well as high-voltage electrical transmission lines and transformers. Given modern technology, nonionizing radiation from power lines, personal wireless devices, cell phone towers and other sources is practically unavoidable.

Evidence of health effects from EMF is inconclusive, and the probability that EMF exposure is a health hazard seems small. Nevertheless, exposure to high levels of nonionizing energy, at radio-wave frequencies, for example, can damage the structure and function of the nervous system. Microwave frequencies below 3,000 megahertz can penetrate the outer layers of the skin, be absorbed in the underlying tissues, and result in all the known biological effects of heating—burns, cataracts and possibly death.

Some scientists claim that human tissue, including the brain, may be affected at nonthermal levels. Regrettably, differences in exposure parameters, such as frequency, orientation, modulation, power density and duration, make it difficult to directly compare experiments and draw specific conclusions. It is important to remember as well that, perhaps expectedly, interpretations of findings in this area of investigation are shrouded in controversy, particularly because special interests may influence some of the research. The publication of findings does not necessarily scientifically validate a study.

RADIO-FREQUENCY FIELDS. At lower levels of exposure, evidence for specific effects that may occur as a result of direct neural interactions with radio-frequency fields is sparse. In addition, many of the studies that claim provocative results have yet to be rep-

Given modern technology, nonionizing radiation from power lines, personal wireless devices, cell phone towers and other sources is practically unavoidable.

licated by independent laboratories. Other studies describe potential associations. For example, a recent report suggests that the low-intensity electromagnetic field of geomagnetic storms—disturbances in the earth's magnetic field caused by gusts of solar wind—may have a subtle but measurable influence on suicide incidence in women.

In recent years, cell phones, which transmit and receive at radio frequencies, have become ubiquitous. Researchers have investigated whether these low-intensity radio waves influence the central nervous system and cognitive performance. A few studies concluded that cell phone exposure actually enhanced certain aspects of cognitive performance as measured by reaction time and accuracy; others showed no difference, and a few, including a recent investigation, showed that exposure had detrimental effects in specific contexts such as attentional tasks. Replication of either negative or positive effects of exposure on cognition is sorely lacking in the scientific literature, and more work is required to explain and reconcile reports of contradictory results. Even if effects exist, they are likely to be very small. **M**

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

Head Games

Match wits with the Mensa puzzler
BY ABBIE F. SALNY

1 James has two more brothers than he has sisters. His sister Jane has three times as many brothers as sisters. There are no more than 10 in the family. How many boys and girls?

2 How many common English words can you make using all of the following letters?

A E L P T

3 What is the number that is one more than one tenth of one half of one fourth of 8,000?

4 Which of the following words is least like the others?

TIME

STOP

CASH

PART

STRAW

5 The logic professor posted this note on the door of his Tuesday class: "Sorry to miss class. We will meet again on the second day after

the day before the day after tomorrow." When will they meet?

6 The same six letters can be arranged to complete the sentences below.

I am an amateur archaeologist. On one _____ in a remote country village in Sicily, I saw a small floor of _____ that turned out to be ancient Roman.

7 A definition is given of one word. If that word is split into two parts, there is a definition for each.

**One word: Show up again
Two words: (1) Cut down a crop
(2) A fruit**

8 Start with the number of points on a snowflake, multiply by the earliest age you can be a nonagenarian, then divide by the

number of feet in a fathom. What do you have?

9 Figure out the pattern below and fill in the missing letter.

7, 3, 2, t

5, 1, 9, f

3, 1, 4, ?

10 Fill in the box below with three more words reading the same across and down, using five Rs, five Es, three Ss, two Os and one V.

R	O	S	E
O			
S			
E			

Abbie F. Salny, Ed.D., was the supervisory psychologist for American Mensa (www.us.mensa.org/sciamm) and Mensa International (www.mensa.org) for more than 25 years. She is the author and co-author of many challenging puzzle books, including the Mensa Think-Smart Book and the Mensa 365 Brain Puzzlers Page-A-Day Calendar (Workman Publishing).

Answers

S	R	R	E
R	E	E	S
R	E	V	O
E	S	O	R

10.

1. Six boys and three girls.
2. Plate, petal, pleat and leapt. (Good for you if you thought of lepta and tepali!)
3. 101.
4. Cash. It is the only word that does not read backward to form another one.
5. Friday.
6. Ramble, marble.
7. Reappear, reap, pear.
8. 90. ($6 \times 90 = 540 \div 6 = 90$.)
9. E. (Add the sets of numbers; the first letter of each sum is the answer. $7 + 3 + 2 = 12$; "t" for twelve. $5 + 1 + 9 = 15$; "f" for fifteen. $3 + 1 + 4 = 8$; "e" for eight.)

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