SPEECH BOTTLENECK • A PEOPLE WITHOUT NUMBERS

SCIENTIFIC AMERICAN MIND

THOUGHT • IDEAS • BRAIN SCIENCE

October/November 2006 www.sciammind.com

Special Report:
How Your Body Reveals What You Think

Flashes of Insight in a

BRAINSTORM

Tap Your Creative Powers *page 38*

Regain Lost Scents

Early **Autism** Detection

Evolution of **Language**

Electrical Channels for Thought

New Light on **Nature vs. Nurture**

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MIND
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COVER IMAGE BY JEAN-FRANCOIS PODEVIN

Point of View

Each of us has a rich inner mental life, one that seems inaccessible to everyone else. To others, we believe, we represent a kind of human terra incognita. After all, how can anybody really know what is on our mind?

As it turns out, however, our feelings and thoughts are only too visible to those who know how to look. You will learn why in our special report, "The Body Speaks." Tiny "microexpressions" involuntarily flit across our face, revealing our emotions, as Siri Schubert explains in "A Look Tells All," starting on page 26. In "Gestures Offer Insight," beginning on page 20, Ipke Wachsmuth describes how we make hand or other motions to add shades of meaning to words as we converse. And when we fib, our very physiology can give us away, Thomas Metzinger details in "Exposing Lies"; go to page 32.

Getting an outside vantage point also helps us find other things that can seem hidden or unavailable: novel ideas. Basic knowledge of a given field helps, of course, in the quest for a problem's solution. But simply proceeding step-by-step like a computer will get you only so far. To summon those priceless flashes of insight takes a new point of view. "The Eureka Moment," by Guenther Knoblich and Michael Oellinger, tells why on page 38.

Shifting perspective again, we recognize the value of insider knowledge and experience for sorting good ideas from bad in pop psychology. We may wonder, does a given therapy work as advertised? How is the average person to know what to trust? Now we are pleased to offer help: "Facts and Fictions in Mental Health," a new column by psychologists Hal Arkowitz and Scott O. Lilienfeld. First up: self-help books. Do they really help? Flip to page 78 to get their take.

What's your perspective on this issue's offerings? We'd like to know.

Mariette DiChristina
Executive Editor
editors@sciam.com

A SPECIAL INVITATION TO READERS

What do you like about *Scientific American Mind*? What could it do better? What topics do you want to see the magazine cover? Send your ideas to Mariette DiChristina, Executive Editor, at mdichristina@sciammind.com

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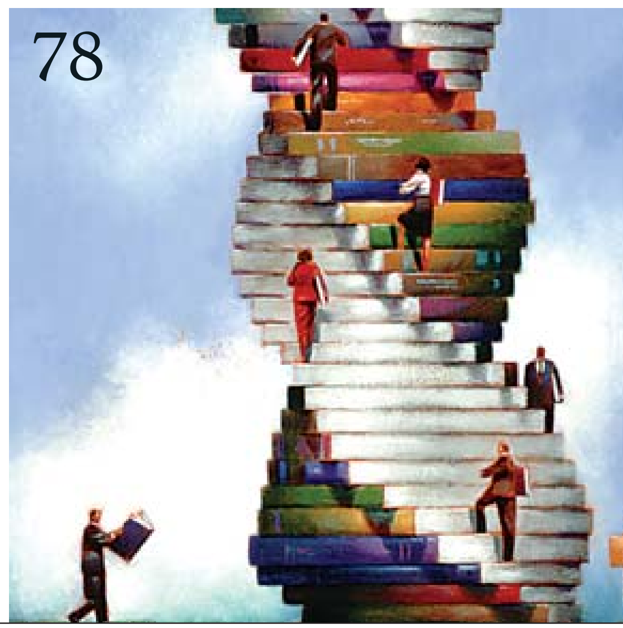
Volume 17, Number 5, October/November 2006

FEATURES

DEPARTMENTS



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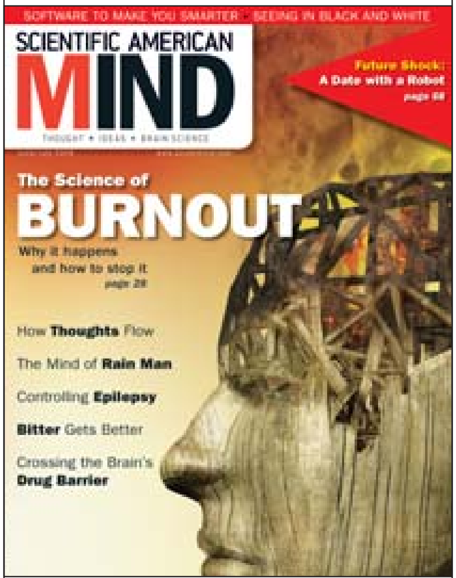


LONG, SLOW BURN

Regarding Ulrich Kraft's "Burned Out": Herbert J. Freudenberger may have coined the term "burnout syndrome" in the 1970s, but he was not the first to notice the phenomenon. In *The Wealth of Nations* in 1776, Adam Smith observed that many people could only work at full output for a small number of years and that it was the bosses' job "rather to moderate, than to animate" their workers. George Combe in 1827 wrote that work must be enjoyable, which it could not be if it was too hard or too long: otherwise the only happiness is retirement.

Early in the 20th century the Yerkes-Dodson Law related increasing stress and motivation to an inverted U-shaped curve for work output; at the highest level of stress, output dropped to zero. Behavioral researcher B. F. Skinner discussed how a bricklayer could "burn himself out" in 1953. He called it "abulia," or absence of behavior, and described it as the consequence of too much work being expected.

An old Scottish proverb puts it in a nutshell: "The hired horse never tires." This expression implies that the hirer's attitude can cause work woes. Competition and the profit motive seem to be at the root of the problem in an industrial society.

Bill Taylor
Nairn, Scotland

"Burned Out" was right on target with the observation by Juergen Staedt that recognizing effort motivates high performers by rewarding them for their extra stress. One need only look at the cycle of outsourcing to see how employees at all levels feel compelled to increase their productivity, further contributing to their stress. When the organizational ax falls in spite of their efforts, as Staedt notes, they take an even harder hit.

The remedies mentioned do work well, and a stable relationship and supportive spouse are essential. I identify with their subjects: at age 50, I switched careers from graphic production to teaching. It was stressful, but friends and family were supportive, and that made the difference.

Frank Tingle
Etobicoke, Ontario

An enlightening book on this subject is *Professional Suicide: A Survival Kit for You and Your Job,* by Donald W. Cole (McGraw-Hill, 1981). Cole, a consultant, investigated why promising employees with symptoms resembling burnout would commit "professional suicide" by leaving for lesser jobs or remaining on staff but "retiring." He blamed a corporate culture with vague goals, which penalized the best employees and allowed the less able to work it to their advantage. Upper managers would usually terminate his services when he reported that the problem was not with the employees but with them.

Peter Vaculik
Ann Arbor, Mich.

BRAIN CELL CHATTER

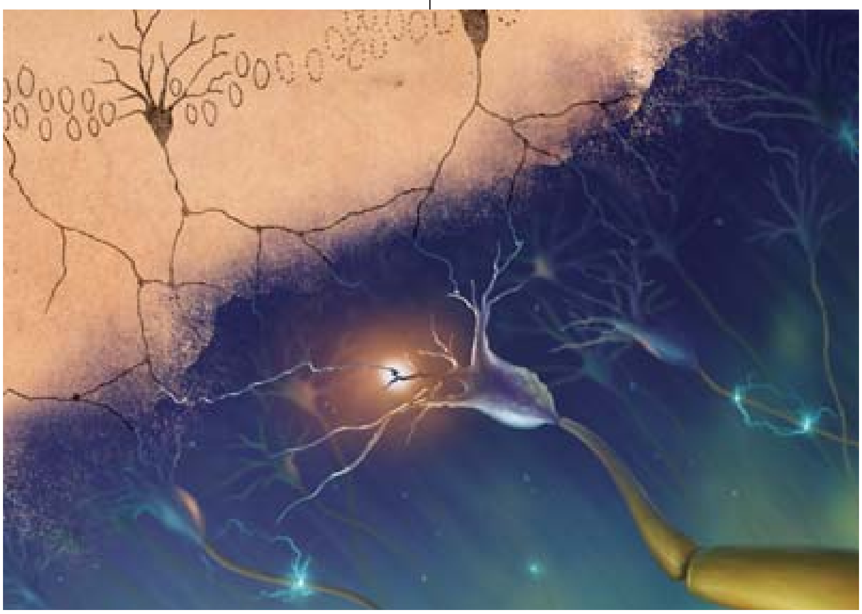
"Beyond the Neuron Doctrine," by R. Douglas Fields, sheds new light on the old debate on how neurons communicate. We agree with him that more scientific work needs to be done before answering the question: How are waves so well coordinated in the human brain? One interesting research area focuses on the question: How are physics and human information processing linked? Perhaps in future research, we can look at quantum physics to come to a more basic understanding of the mechanisms behind neuron communication, and as a result we might come to a better understanding of the human brain.

Maurits van den Noort
Peggy Bosch
University of Bergen, Norway

FIELDS REPLIES: Whether quantum physics may help unlock this secret I do not know, but I have no doubt that uniting forces of biology, mathematics and physics will be required to pry open this mystery.

A collision between biology and physics sparked the science of electrophysiology the day Luigi Galvani touched bare metal forceps to a skinned frog leg and it twitched with life. Alessandro Volta dismissed Galvani's 1791 startling discovery of "animal electricity" as an electrochemical reaction between metal and salty body fluids, an argument that led him to discover the chemical battery. Human brain waves were not seen until 1929, by an obscure German psychiatrist, Hans Berger, who was searching for a physical basis for mental function.

From our first glimpse of them to today, brain waves seem complicated, puzzling and difficult to analyze. They have been viewed from one extreme to the other: dismissed as an epiphenomenon—like the sound of an engine, a consequence of its operation but of no functional significance—and conjured as the imagined physical basis for mental telepathy. Unlike the easily comprehended messenger function of the nerve impulse, brain waves are not taught or understood by most neurobiologists. The complicated signals are revealed only with specialized equipment and sophisticated computers. Today the most advanced mathematics and physics are applied to analyze brain waves: Fourier analysis, power spectra, coherence measurements, vector analysis, eigenvalues, wavelet analysis, coupled oscillator dynamics—most of which are outside the expertise of biologists. Brain waves fascinate us, because their violent electrical storm shifts in complex ways with the winds of our mental state and move with the currents of our thoughts.



Scientists have settled an old debate about how brain cells communicate.

After reading "Beyond the Neuron Doctrine," I have a question: Is there a significant difference in the power spectrum of brain-wave activity among humans with different brain-related disorders? For example, do children who are mentally disabled or autistic have significant differences in the power spectrum of their brain waves (which I assume are measured by EEGs) compared with those of "normal" children?

Tom Fabricius
via e-mail

FIELDS REPLIES: Yes, readings of brain waves are being applied in early diagnosis of sensory and cognitive impairments—and not just in infants. Brain waves evoked by test stimuli allow doctors to diagnose deafness in newborns, and EEGs are useful in evaluating some forms of mental retardation in children, such as Angelman's syndrome. They also are being used experimentally to detect attention-deficit hyperactivity disorder (ADHD), schizophrenia and—before symptoms are even apparent—mild cognitive impairments in the elderly caused by Alzheimer's.

CONTROLLING EPILEPSY

The fascinating article on "Controlling Epilepsy," by Christian Hoppe, gives me the self-confidence to report that I suffered epilepsy-type seizures for 21 years until a wonderful neurosurgeon performed an operation that gave me back a normal life. It is a pleasure for me to talk about this because I had to experience what others are suffering through in controlling epilepsy: there is hope!

Anna Victoria Reich
Albuquerque, N.M.

My 19-year-old daughter was diagnosed with epilepsy at the age of 12. Your article gave me more knowledge and a deeper understanding of the surgical procedure and tests that go along with it. For that, I thank you.

But I cringed when I read the words "grand mal" not once but twice. Do you know that the expression means "big evil"? Using it perpetuates the religious interpretation of the condition that you discussed: that those who endure epilepsy are receiving God's punishment or are influenced by the work of demons. Use the proper terminology: "tonic-clonic."

Cindy Carrothers
Minnedosa, Manitoba

Head Lines

EMPICS/LANDOV

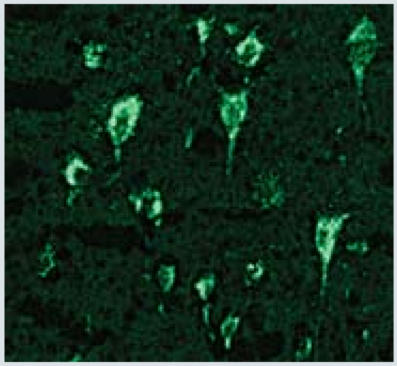
Color Is Quickest Decoder

The average person can focus on only three objects at once, yet he or she can follow a soccer game and accurately estimate, in just half a second, how many players from each team are on the field. Justin Halberda, a Johns Hopkins University psychologist, explains that "people can focus on more than three items at a time if those items share a common color." The color coding enables them to perceive separate individuals as a single set.

Halberda showed volunteers arrays of colored dots for 500 milliseconds—too brief for counting—then asked how many dots of a given color they had observed. Even with scenes of 35 dots in several colors, participants were 87 percent accurate, which indicates the human brain can carry out parallel processing of sets in a short time. Color, Halberda says, seems to be the easiest "sorting tool," but he is now looking at arrays differing in size, shape and brightness. If another feature holds up, perhaps Italy's *il Azzurri* and France's *les Bleus* can both wear their blue home uniforms in the next World Cup soccer final. *—Jonathan Beard*

Protein Prevents Neuron Death

Researchers have discovered a protein that might prevent neurons from dying after traumatic brain injuries such as those caused by severe car accidents. Seong-Seng Tan of the Howard Florey Institute in Australia and his colleagues tested the activity of 18,000 genes in surviving neurons (*right*) that surrounded an injury site in the brains of mice. All but one gene—responsible for generating the protein N4WBP5—drastically reduced their protein production during the 24 hours after injury. When Tan manipulated stressed brain cells into producing more N4WBP5 than usual, a dramatically higher number of cells survived.



Protein kept these neurons alive.

The Australian team is currently trying to delineate the precise mechanisms that underlie the N4WBP5 action. Knowing how the protein may prevent cell death could lead to drugs that can simulate its function, says Andrew Ottens, an outside expert and professor of psychiatry and neuroscience at the University of Florida. He cautions, however, that further studies are needed, including tests that determine whether N4WBP5 performs its function for more than 24 hours, because in many cases "neurons continue to die for days after traumatic injury." *—Nicole Branan*

Visions for Psychedelics

A single dose of psilocybin, the active ingredient in the infamous psychedelic mushrooms indigenous to Mexico, triggered long-lasting mystical experiences in several dozen middle-aged volunteers enrolled in an unusual study at Johns Hopkins University.

Roland Griffiths and his colleagues brought 36 people into the laboratory for an eight-hour session during which they experienced their first psychedelic high. Two thirds of them said that the trip was among the most profound spiritual events in their life, Griffiths reports. A third rated it as their number-one awakening, and their family and co-workers said they seemed happier in the months after the experiment, according to a follow-up study just concluded.

Griffiths says he embarked on the controversial experiment because psychedelics constitute "a whole class of drugs we know very little about." Research came to a halt after investigators such as Harvard University's Timothy Leary in the heady 1960s swallowed their own research pills in the name of science. Griffiths says the findings suggest these drugs, or safer versions of them, could be used to treat addictions, because many recovery programs are based on models of spirituality. The drugs could also help overcome depression.

Johns Hopkins recruited people with no history of mental illness or psychedelic drug use. Each volunteer received eight hours of preparation. Their trip took place in a living room setting with two monitors present. Half received the real drug, and the others were given an amphetamine or a placebo. According to Griffiths, the subjects who received psilocybin said they "had a sense of pure awareness. They described feeling infinite love, tenderness and peace. Everything was experienced in the present; the past and future had no meaning." Nevertheless, a third of these volunteers felt significant fears afterward, and some experienced paranoia. "These drugs should not be used recreationally," Griffiths notes. *—Jamie Talan*

More Success Than IQ

Psychologist Robert Sternberg never forgot the low IQ score he earned as a child. Now his theory of "successful intelligence," which he says is a better index of brain power, will be put to a real-life test. This fall undergraduate applicants to Tufts University, where Sternberg is the college dean, will be given a chance to write an optional essay and attend an in-person session where they will respond to videos and pictures, leading to an index for each volunteer.

Robert Sternberg charts intelligence.

In a recent study Sternberg matched the successful-intelligence scores of 777 college students at 13 U.S. colleges against their first-year grade point average, the common yardstick used to judge the predictive power of an applicant's Scholastic Aptitude Test (SAT) scores. The successful-intelligence quotient was twice as effective as the SAT number.

Tufts may eventually use the scores to help choose among the growing number of applicants who meet its academic standards. Sternberg is pleased that minority students in the recent study did not lose ground when their successful-intelligence scores were considered along with high school GPAs and SATs. Usually when compounding such predictors, "you increase ethnic differences," Sternberg says. He hopes that his or other tests of real-life abilities will give savvy or creative minority students a better chance to shine. But the jury is still out, says Claremont McKenna College psychologist Diane Halpern, who notes that the sample of minority students may have been too small to capture group differences. —*Temma Ehrenfeld*

Schizophrenia: One Step Closer

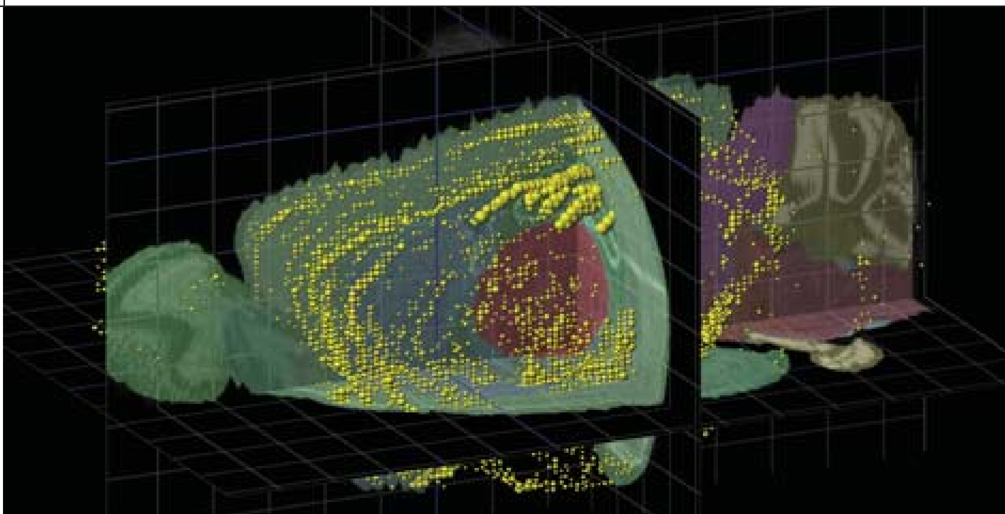
By stimulating dead brain tissue, neuroscientists have concluded that a specific receptor found in the outer layer of neurons functions differently in schizophrenic brains. Schizophrenia, a disorder affecting about 1 percent of Americans, stems partly from genetic factors. Current treatments alleviate only a small fraction of the symptoms, which may include hallucinations, paranoia and disorganized behavior.

The N-methyl-D-aspartate (NMDA) receptor is one of several which bind to glutamate, a key neurotransmitter. In schizophrenic brains, scientists believe the function of NMDA receptors, which normally play a critical role in many neural processes, may be disrupted. How this dysfunction in binding contributes to schizophrenia is unclear, but this latest examination provides the first direct evidence of a correlation to diminished NMDA-receptor function.

The work, led in part by Chang-Gyu Hahn, professor of psychiatry at the University of Pennsylvania, also reveals that decreased NMDA-receptor function coincides with increased activation of another receptor, erbB4. This second receptor is activated by the neurotransmitter neuregulin-1, which is produced by a gene, variations of which indicate an increased probability of schizophrenia. Hahn says that a drug designed to suppress erbB4 activation might alleviate symptoms of schizophrenia better than current treatments do.

Although understanding molecular dynamics using dead brain tissue seems implausible, Hahn and his colleagues invented a means to stimulate the tissue and measure the resulting activation of receptors—in this case, in 28 brains at autopsy. Previous techniques measured only the quantity of receptors. "We hope that this technique will open new avenues of research," Hahn says. —*Brie Finegold*

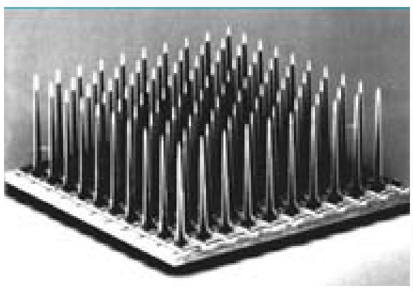
PAT GREENHOUSE *Boston Globe* (*top*); IMAGES.COM/CORBIS (*bottom*)



Brain Atlas Released

The Allen Institute for Brain Science in Seattle has completed a three-dimensional, Web-based atlas of the mouse brain that details the expression of its 21,000 genes. The enormous database at www.brain-map.org can be freely accessed by the public. A sample image (*above*) shows the presence of a gene, *Emp 1,* in the left hemisphere. Each yellow sphere represents expression of the gene; larger spheres correspond to greater expression density. The institute notes that 90 percent of mouse genes have a direct human counterpart and that the data could therefore provide insights into how the human brain works and how illnesses such as Alzheimer's and epilepsy compromise it. Scientists plan to start compiling a similar database for the human cortex, which is central to higher-order thinking. *—Mark Fischetti*

Cortex Implants Considered



Tiny array, four millimeters on a side, could help paralyzed patients.

A paralyzed man with an implant in his brain was able to operate a television, play a simple video game and flex a robotic hand using only his thoughts, researchers reported in July. They say such devices hold long-term promise for restoring function to paralyzed individuals. But a review of other neural prosthetics indicates that for now, less invasive techniques may provide the same abilities at less risk.

Two years ago a surgeon inserted a 16-square-millimeter, pincushionlike array of electrodes (*right*) into the motor cortex of 26-year-old Matthew Nagle, whose spinal cord had been severed by a knife wound to the neck. The implant protrudes from the skull and links via a cable to a computer. While connected, Nagle crudely directed an on-screen cursor as he envisioned it moving in various directions. He functioned with the implant for nearly a year. A second recipient had much less consistent control, but two others have shown results similar to Nagle's, according to neuroscientist John Donoghue of Brown University, who led the experiments and is chief scientist for the marketer for the system, Cyberkinetics Neurotechnology Systems in Foxborough, Mass.

The system could complement existing technology that allows paralyzed people to control a computer through EEG (brain-wave) electrodes on the scalp, Donoghue says, but other investigators do not see the point. "What was achieved could have been done with something off the shelf," says neurobiologist Miguel Nicolelis of Duke University, who is experimenting with fully implantable electrodes, which would presumably carry less risk of infection than a device that extends from the skull. And "if you can get the same function without putting something into the brain, you'd prefer to do that," adds neurologist Jonathan Wolpaw of the Wadsworth Center in Albany, N.Y., which is testing a home EEG system. Implanted electrodes, he says, are years away from practical use. *—JR Minkel*

THE ALLEN INSTITUTE FOR BRAIN SCIENCE (*top*); CYBERKINETICS NEUROTECHNOLOGY SYSTEMS, INC. (*bottom*)

Television can numb children's brains—in this case, a good thing. Researchers at the University of Siena in Italy used a needle to take blood from three groups of children ages 7 to 12. One group had no distraction, one group was distracted by their mothers, and one group watched cartoons. The undisturbed kids reported the highest level of pain from the procedure, those distracted reported modest pain, and those watching television reported the least pain.

Strokes in Americans will cost the country $2.2 trillion from now until 2050 in ambulance, hospital, rehabilitation, nursing home and medication costs and in lost earnings, according to a University of Michigan analysis. Stroke is the leading cost of adult disability in the U.S. Individuals can reduce their risk by stopping or not smoking, losing weight, reducing cholesterol and blood pressure, and exercising.

Post-traumatic stress disorder across a community, not just in individuals, has now been shown in several cases, according to the Centers for Disease Control and Prevention: after the September 11 terrorist attack in New York City, the 2002 sniper shootings in Washington, D.C., and the more recent series of sniper attacks in Phoenix. Psychiatrists have no established tools for treating this phenomenon and say community-wide programs must be devised, including mass media campaigns.

Babies Learn to Move

New analysis of infants lends further credence to the rapidly advancing theory of mirror neurons. Key to learning, mirror neurons fire in our brains when we perform physical actions but also fire similarly when we observe other people conducting those same actions. Psychologist Claes von Hofsten of Uppsala University in Sweden has shown that these cells become active before our first birthdays, earlier than scientists had anticipated.

In a 2003 experiment adults stacking blocks shifted their gaze to the site to which they were moving a block a few hundred milliseconds before the object reached the target. They did the same when watching others perform the same task. This year von Hofsten and his colleagues monitored the eyes of infants as they watched a video of a person putting little balls into a pail. Babies learn to perform this task at around nine months of age, suggesting that older infants should be able to anticipate the videotaped action but not younger infants. Sure enough, the eyes of one-year-old babies flicked ahead to the goal as they watched, but six-month-olds gazed willy-nilly.

In a control experiment the children watched animated balls moving to a basket on their own; the one-year-olds showed no anticipation in this case. Von Hofsten says the result indicates that infants evoke their own motor systems to understand other people's actions, thanks to mirror neurons. Neuroscientist Marco Iacoboni of the University of California, Los Angeles, adds that "it is likely that the behavioral change is initiated by a qualitative change in mirror neurons." An interesting next step, he notes, would be to see if differences in gaze can predict autism. *—JR Minkel*

Infants use their mirror neurons to understand actions of other people.

Babies Learn to Speak

Some theorists believe infants enter the world with "hard-wired" neurons that are preadapted for both understanding and producing speech. Others believe that speech is learned through experience. Now research reveals how a baby's speech centers function at five days old, then six months, then a year.

Neuroscientist Patricia Kuhl of the University of Washington, working with colleagues at the University of Helsinki in Finland, used a new technique, magnetoencephalography (MEG), to measure brain activity by sensing the magnetic fields neurons create when they fire.

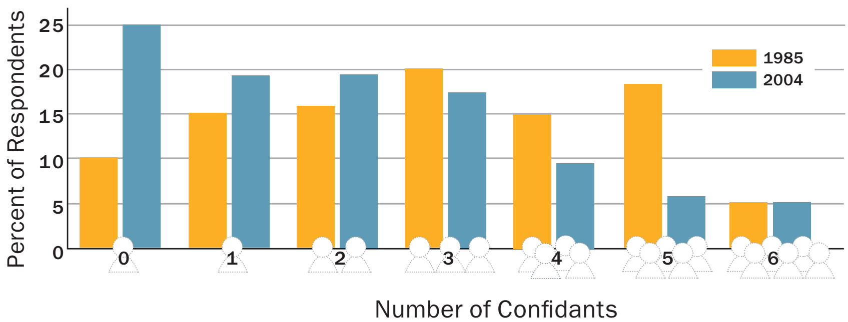
The results lend empirical evidence to the notion that speech is indeed learned.

"When we played three kinds of sounds—pure tones, a three-tone harmonic and the Finnish speech sounds PA and BA—for newborns, we saw activity in their auditory centers," Kuhl says. This means they heard and could distinguish the sounds. "But there was no activity in the inferior frontal cortex," where speech production is analyzed and mouth and throat muscles are prepared for talking.

By six months, however, the infants were activating this region when they heard either the harmonic or the speech sounds, and the one-year-olds activated both the auditory and speech-production areas simultaneously, indicating "cross-talk between the areas that hear and produce speech," Kuhl says. Babies, she explains, need time to experiment: to make sounds, listen to them, and link what they hear to what their speech muscles are doing. Once they have figured out this process, they can start listening to and mimicking other speakers. *—Jonathan Beard*

GETTY IMAGES (*top*); KEI UESUGI *Getty Images* (*bottom*)

More work hours, and moving, have limited the people in whom we trust.



Confiding in No One

Newly published analyses of a 2004 survey indicate that Americans' social safety net is shrinking. On average, the 1,467 respondents listed only two people with whom they discuss important matters. In 1985 a similar mix of volunteers answering a comparable large survey reported an average of three confidants.

Also surprising: the most frequently reported number of confidants was zero, rather than three in 1985. Principal investigator Lynn Smith-Lovin, professor of sociology at Duke University, speculates that recent increases in time spent at work and frequent changes of residency could explain this striking change.

Other differences include shifts in the way individuals select whom to trust. More Americans today confide exclusively in relatives, especially spouses, as opposed to associates from social organizations or work, who were cited much more often in the previous results. And yet people with higher levels of secondary education tend to confide more in acquaintances outside the family; Smith-Lovin attributes this phenomenon to the tendency of highly educated people to have larger discussion networks. She and her colleagues are now reinterviewing participants to try to better explain these and other apparent trends.

—Brie Finegold

Patch Could Lift Depression

Introduced decades ago as the next step in antidepression pills, monoamine oxidase inhibitors (MAOIs) soon fell out of favor. Extremely effective in some people, they caused potentially lethal blood pressure spikes in others because of interactions with food in the gut. That and the subsequent rise of selective serotonin reuptake inhibitors (SSRIs) put them on a shelf. But a new skin patch has resurrected the drugs from obscurity.

The patch, Emsam, developed by Somerset Pharmaceuticals and marketed by Bristol-Myers Squibb, delivers an MAOI, selegiline, directly and continuously into the bloodstream, eliminating exposure to the gut and maximizing its effect in the brain. "This is big news for long-term patient benefit," says Alexander Bodkin, chief of clinical psychopharmacology research at Harvard University's McLean Hospital, who was part of the research team. "Now those who have been untreatable could be safely treated."

That is about 30 percent of the 14 million Americans who have major depressive disorder, Bodkin says. These patients, suffering with entrenched symptoms such as oversleeping and overeating, typically are not helped with prevailing SSRIs such as Prozac or standard talk therapies. The transdermal dose significantly improved symptoms in studies in adults. The Food and Drug Administration recently approved the commercial version of the patch.

Outside experts are still taking a wait-and-see attitude about widespread application of a class of drugs that was so dubious for so long. "It's too early to tell," says Michael Thase, professor of psychiatry at the University of Pittsburgh Medical Center, although he adds that the studies do suggest that the selegiline patch compares favorably with other modern antidepressants.

—Leslie Sabbagh

GETTY IMAGES (*top*); SCIENTIFIC AMERICAN (*middle*); BRISTOL-MYERS SQUIBB (*bottom*)

Determining Nature vs. Nurture

Molecular evidence is finally emerging to inform the long-standing debate

BY DOUGLAS STEINBERG

PAUL WHITEHILL *Photo Researchers, Inc.*

PSYCHOLOGISTS, psychiatrists and neuroscientists have jousted for years over how much of our behavior is driven by our genes versus the environments in which we grow up and live. Arguments have persisted because there has been little hard evidence to answer basic questions: How exactly do genes and environment interact to determine whether someone will become depressed, say, or schizophrenic? And can environmental interventions such as drugs or psychotherapy really alleviate disorders that are largely determined by genes?

A field called epigenetics has finally begun to address some of these issues. Its practitioners study how tiny molecules stick to, or become unstuck from, two main targets in a cell's nucleus: the DNA in and around a gene and the histones—the proteins around which chromosomes spool. These tiny molecules are known as methyl and acetyl groups, and their presence or absence at target sites controls whether particular genes can generate proteins, the workhorses of most physiological processes.

Until a couple of years ago, the conventional wisdom in biology held that such molecular changes occur in primitive cells, usually during embryonic and fetal development, not in mature cells such as a child's or adult's neurons. Then researchers proved that epigenetic changes are indeed at work

(The findings suggest that a **mother's parenting style** can affect the activity of a child's genes.)

in mature cells. Now studies are starting to show how environmental cues can stimulate epigenetic changes that could contribute to several psychiatric diseases. Systematic measurement of those changes could eventually indicate how the environment influences the genetic chemistry underlying many human behaviors.

Schizophrenia and Depression

One condition that has begun to yield its epigenetic secrets is schizophrenia, which generally arises when people hit their late teens or twenties. "Something happens during puberty that causes changes in gene expression," notes Dennis R. Grayson, an associate professor of psychiatry at the University of Illinois at Chicago.

That "something" is still unknown. Schizophrenia has not been definitively tied to mutant genes, even though it tends to run in families, and environmental factors show only weak statistical links to the disease's incidence. But it is becoming clearer that epigenetic alterations—triggered perhaps by a convergence of subtle influences—may play a role. Grayson and his colleagues Alessandro Guidotti and Erminio Costa autopsied the brains of schizophrenic patients and found that methyl groups were attached to a gene that helps to form connections between neurons. Earlier postmortem studies showed both a sharp reduction in this gene's activity and an increase in the activity of a gene that promotes attachments of methyl groups to DNA.

Experimental evidence links epigenetic changes to depression as well. Eric J. Nestler, psychiatry department chair at the University of Texas Southwestern Medical Center at Dallas, has proposed a potential animal model of the disease that includes epigenetic changes in the hippocampus, a memory-storing brain region that actually shrinks in some cases of human depression.

To develop this model, Nestler and his co-workers put a small adult male mouse into the cage of a far larger aggressive mouse, which soon attacked the newcomer. Ten minutes later they placed a plastic barrier between the mice, which stopped the attacks but did not stop the little rodent from seeing, hearing and smelling its nemesis. A small mouse placed in this situation for 10 days typically displayed depressionlike social avoidance.

The researchers discovered that such treatment also caused methyl groups to stick to histones (the DNA-spooling proteins) in the hippocampus. This action suppressed a gene that, as a result, failed to generate a protein suspected of helping the brain adapt to stress. What is more, the small mouse ceased exhibiting social avoidance when it received antidepressants, which restored the gene's activity.

Nestler says he does not know yet how a hostile environment prompts methyl groups to stick to histones, but his study suggested why the antidepressant works: it causes acetyl groups to attach to the histones, thereby counteracting the effects of the methyl groups. Nestler and other scientists are now trying to create compounds that will tinker with specific epigenetic mechanisms.

Maternal Influence

Fearfulness is another psychological condition that can arise from the epigenetic effects of environmental influences. Michael J. Meaney, a psychiatry professor at McGill University, has found that when a rat pup receives less licking and grooming from its mother it is more fearful and more reactive to stressors as it matures.

The team found that a hippocampal gene sheds methyl-group molecules during the first week of a pup's life if its mother is a "high licker." Pups of low lickers do not prune the molecules. An adoption experiment proved that licking triggers these events: when the team entrusted pups born to mothers of one licking type to mothers of the other type, the genes' methyl status reflected the licking type of the adoptive parent. Licking is believed to exert its effect by raising the pups' thyroid-hormone production and activity of the neurotransmitter serotonin.

Meaney says he encountered "a fairly intense level of skepticism" when he first presented his results, because they imply that epigenetic changes can occur in mature cells, not just in the immature cells present in an embryo or fetus. The social implications of his work were also unsettling. The findings suggest that a mother's parenting style can have very different effects on the activity of a child's genes. Meaney and others are now also studying hundreds of human mother-infant pairs to learn how a stressful pregnancy might affect a baby's later development.

Applying epigenetics to the brain is just beginning, but the field is ramping up as technologies to monitor molecular changes improve. Do not expect the findings to bring speedy cures for psychiatric ills, however. For years, cancer researchers have investigated epigenetic influences on tumor formation, yet cancer remains unvanquished. Epigenetics may indeed unveil what is happening at the intersection of genes and environment—between nature and nurture—but we will be relying on psychiatrists and psychologists for a long time to come. **M**

> (It is becoming clearer that **epigenetic alterations** may play a role in schizophrenia.)

DOUGLAS STEINBERG is a freelance science writer in New York City.

The Neurology of Aesthetics

How visual-processing systems shape our feelings about what we see

BY VILAYANUR S. RAMACHANDRAN AND DIANE ROGERS-RAMACHANDRAN

WHAT IS ART? Probably as many definitions exist as do artists and art critics. Art is clearly an expression of our aesthetic response to beauty. But the word has so many connotations that it is best—from a scientific point of view—to confine ourselves to the neurology of aesthetics.

Aesthetic response varies from culture to culture. The sharp bouquet of Marmite is avidly sought after by the English but repulsive to most Americans. The same applies to visual preferences; we have personally found no special appeal in Picasso. Despite this diversity of styles, many have wondered whether there are some universal principles. Do we have an innate "grammar" of aesthetics analogous to the syntactic universals for languages proposed by linguist Noam Chomsky of the Massachusetts Institute of Technology?

The answer may be yes. We suggest that universal "laws" of aesthetics may cut across not only cultural boundaries but across species boundaries as well. Can it be a coincidence that we find birds and butterflies attractive even though they evolved to appeal to other birds and butterflies, not to us? Bowerbirds produce elegant bachelor pads (bowers) that would probably elicit favorable reviews from Manhattan art critics—as long as you auctioned them at Sotheby's and did not reveal that they were created by birdbrains.

In 1994, in a whimsical mood, we came up with a somewhat arbitrary list of "laws" of aesthetics, of which we will describe six: grouping, symmetry, hypernormal stimuli, peak shift, isolation and perceptual problem solving. For each law, we will explain what function it might serve and what neural machinery mediates it.

Pay Attention!

Let us consider grouping first. In (*a*), you get the sense of your visual system struggling to discover and group together seemingly unrelated fragments of a single object, in this case a dalmatian. When the correct fragments click into place, we feel a gratifying "aha." That enjoyable experience, we suggest, is based on direct messages sent to pleasure centers of the limbic system saying, in effect, "Here is something important: pay attention"—a minimal requirement for aesthetics. Fashion designers understand the principle of grouping. The salesclerk suggests a white tie with blue

COURTESY OF RICHARD GREGORY (*top*); MICHAEL FREEMAN *Corbis* (*bottom*)

(When the correct fragments **click into place**, we feel a gratifying "aha.")

Evolution has had a hand in shaping the **appeal of symmetry**.

flecks to match the blue of your jacket.

Grouping evolved to defeat camouflage and more generally to detect objects in cluttered environments. Imagine a tiger hidden behind foliage (*d*). All your eye receives are several yellowish tiger fragments. But your visual system assumes that all these fragments cannot be alike by coincidence, and so it groups them to assemble the object and pays attention. Little does the salesperson realize that he or she is tapping into this ancient biological principle in selecting your tie.

Evolution also had a hand in shaping the appeal of symmetry. In nature, most biological objects (prey, predator, mate) are symmetrical. It pays to have an early warning alert system to draw your attention to symmetry, leading quickly to appropriate action. This attraction explains symmetry's allure, whether for a child playing with a kaleidoscope or for Emperor Shah Jahan, who built the Taj Mahal (*b*) to immortalize his beautiful wife, Mumtaz. Symmetry may also be attractive because asymmetrical mates tend to be unhealthy, having had bad genes or parasites in their early development.

Let us turn now to a less obvious universal law, that of hypernormal stimuli. Ethologist Nikolaas Tinbergen of the University of Oxford noticed more than 50 years ago that newly hatched seagull chicks started begging for food by pecking at their mother's beak, which is light brown with a red spot. A chick will peck equally fervently at a disembodied beak; no gull need be attached to it. This instinctive behavior arose because, over millions of years of evolution, the chick's brain has "learned" that a long thing with a red spot means mother and food.

Tinbergen found that he could elicit pecking without a beak. A long stick with a red spot would do. The visual neurons in the chick's brain are obviously not very fussy about the exact stimulus requirements. But he then made a remarkable discovery. If the chick viewed a long thin piece of cardboard with three red stripes, it went berserk. The chick preferred this strange stimulus to a real beak. Without realizing it, Tinbergen had stumbled on what we call a "superbeak." (He later shared the 1973 Nobel Prize in Physiology or Medicine for his work on animal behavior patterns.)

We do not know why this effect occurs, but it probably results from the way in which visual neurons encode sensory information. The way they are wired may cause them to respond more powerfully to an odd pattern, thereby sending a big "aha" jolt to the bird's limbic system.

What has a superbeak got to do with art? If gull chicks had an art gallery, they would hang a long stick with stripes on the wall, and they would likewise adore it and pay dearly to own one. Art, similarly, stirs collectors to plunk down thousands of dollars for a painting without understanding why it is so compelling. Through trial and error and ingenuity, modern artists have discovered ways of tapping into idiosyncratic aspects of the brain's primitive perceptual grammar, producing the equivalent for the human brain of what the striped stick is for the chick's brain.

A related principle, called peak shift, plays a role in the appreciation of caricature or even good portraiture. Features that make a particular face (for example, George W. Bush's) differ from the "average" of hundreds of male faces are amplified selectively so the result looks even more Bush-like than Bush himself. In 1998 philosopher William Hirstein of Elmherst College and I (Ramachandran) suggested that cells in the monkey brain that are known to respond to individual faces (such as Joe, the alpha male) will do so even more vigorously to a caricature of the face than the original. This strong response has now been confirmed in experiments by Doris Tsao of Harvard University.

c

GUSTAV KLIMT, "STUDY OF A NUDE." PHOTOGRAPH BY GÉRARD BLOT *Réunion des Musées Nationaux/Art Resource, NY*

Why Less Is More

We turn to the next two related principles: isolation and perceptual problem solving, or peekaboo.

Any artist will tell you that sometimes in art "less is more"; a little doodle of a nude is much more beautiful than a full-color 3-D photograph of a naked woman. Why? Doesn't this phenomenon contradict peak shift?

To resolve this particular contradiction, we need to recall that our brains have limited attentional resources—an attentional bottleneck re-

(The very **act of searching** for the hidden object is enjoyable, not just the final "aha" of recognition.)

sults because only a single pattern of neural activity can exist at a time. Here is where isolation comes in. A cleverly contrived doodle or sketch (*c*) allows your visual system to spontaneously allocate all your attention to where it is needed—namely, to the nude's contour or shape—without being distracted by all the other irrelevant clutter (color, texture, shading, and so on) that is not as critical as the beauty of her form conveyed by her outlines.

Evidence for this view comes from autistic children with savant skills such as Nadia. She produced astonishingly beautiful drawings, perhaps because, while most of her brain was functioning suboptimally, she may have had an island of "spared" cortical tissue in her parietal lobe, which is known to be involved in one's sense of artistic proportion. Hence, she could spontaneously deploy all her attentional resources to this one spared "art module." (Once she grew up and gained other social skills, her artistic skills vanished.) Bruce Miller of the University of California, San Francisco, has shown that even some adult patients who develop a degeneration of their frontal and temporal lobes (called frontotemporal dementia) suddenly develop artistic talents, possibly because they can now allocate all their attention to the parietal lobes.

A related "law" of aesthetics is peekaboo. In the ninth century A.D. Indian philosopher Abhinavagupta discovered this effect, which Austrian-British art historian Sir Ernst Gombrich rediscovered in the 20th century. An unclothed person who has only arms or part of a shoulder jutting out from behind a shower curtain or who is behind a diaphanous veil is much more alluring than a completely uncovered nude. Just as the thinking parts of our brains enjoy intellectual problem solving, the visual system seems to enjoy discovering a hidden object. Evolution has seen to it that the very act of searching for the hidden object is enjoyable, not just the final "aha" of recognition—lest you give up too early in the chase. Otherwise, we would not pursue a potential prey or mate glimpsed partially behind bushes or dense fog. Every partial glimpse of an object (*d*) prompts a search—leading to a mini "aha"—that sends a message back to bias earlier stages of visual processing. This message in turn prompts a further search and—after several such iterations and mini "ahas"—we arrive at the final "aha!" of recognition. The clever fashion designer or artist tries to evoke as many such mini "ahas," ambiguities, peak shifts and paradoxes as possible in the image.

We have barely touched on more elusive aspects of aesthetics such as "visual metaphor," a pleasing resonance between the visual and symbolic elements of an image. Between the aesthetics of gull chicks and the sublime beauty of a Monet, we have a long journey ahead to truly understand visual processing in the brain. Meanwhile our studies have given us tantalizing glimpses of what the terrain might look like, inspiring us to continue our pursuit. M

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

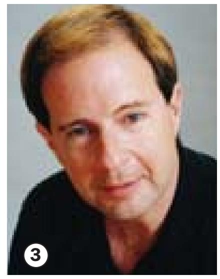
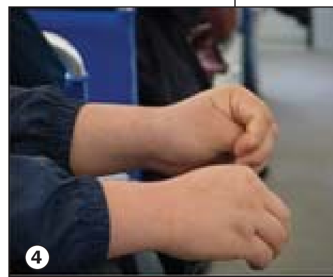
(Further Reading)

- **Inner Vision: An Exploration of Art and the Brain.** Semir Zeki. Oxford University Press, 2000.
- **A Brief Tour of Human Consciousness.** V. S. Ramachandran. Pi Press, 2005.

THEO ALLOFS *Corbis*

(calendar)



MUSEUMS/EXHIBITIONS

Trompe l'Oeil: The Art of Illusion

The skill of the painter is the key to this art form. The artist produces two-dimensional images designed to trick the visual cortex into thinking it sees a three-dimensional assemblage of objects. It's an old art form that is still popular today. This exhibition brings together the leading trompe l'oeil painters currently at work across America.

Montgomery Museum of Fine Arts, Ala.
October 7–December 3
334-240-4333
www.fineartsmuseum.com

1 Slocum Puzzle Room at the Lilly Library

Love puzzles? A puzzle enthusiast, author and collector by the name of Jerry Slocum just donated 30,000 puzzles to the Lilly Library, and some 400 of them have gone on exhibit. These are all mechanical puzzles, such as the Rubik's cube or three-dimensional entanglements of metal, wood or glass that you have to figure out how to disassemble.

Lilly Library, Bloomington, Ind.
Ongoing
812-855-2452
www.indiana.edu/~liblilly/index.html

LECTURE

Positive Psychology: The Science of Happiness

Tal Ben-Shahar—a psychologist at Harvard University, instructor of one of the most popular courses there, and author of *The Question of Happiness* (Writers Club Press, 2002)—gives a lecture on the study of happiness according to positive psychology: "the scientific study of optimal human functioning." The lecture is in conjunction with the exhibition "Body Worlds 2."

Museum of Science, Boston
October 4 at 7 p.m.
Free, but seating is limited;
call 617-723-2500
www.mos.org/bodyworlds/?p=special_events

CONFERENCE

Neuroscience 2006

At the Society for Neuroscience's 36th annual meeting, one presidential lecture will be on the molecular neurobiology of Alzheimer's disease. Frank Gehry will also talk about "Architecture and Perception."

Atlanta
October 14–18
202-962-4000, info@sfn.org
www.sfn.org/am2006

MOVIES

2 49 Up

In 1964 director Michael Apted interviewed a group of British seven-year-olds about life and their hopes for the future. Every seven years since then, he has revisited the same (more or less) group, providing time-capsule-like snapshots of the ups and downs of human lives in progress.

U.S. distribution by First Run Features
Theatrical release: October 6
www.firstrunfeatures.com

Running with Scissors

Augusten Burroughs (Joseph Cross) was, as a teenager, sent off to be raised by the family of his mother's therapist. There we have the beginnings of a memoir, on which this film is based, of a bizarre childhood in which Valium, squalor, sexual abuse and Santa Claus figure prominently. The question of what is truth or fiction has been the subject of lawsuits brought after publication of the book in 2002, but the story also functions as a morality play about borderline insanity in a modern family. Ironically, the famously separated Brad Pitt and Jennifer Aniston were producers for the film.

TriStar (Sony Pictures)
Opens October 11
www.sonypictures.com

Pierrepoint/The Last Hangman

Albert Pierrepoint (Timothy Spall) had an odd career: he was the chief executioner of Britain for 14 years. The film takes the viewpoint of the man who took pride in the work that killed 450 men and women—Nazis, traitors, gangsters, jilted lovers and innocents. He was content to make a living from death, but long after he resigned he spoke out against capital punishment, having concluded that hanging solved nothing and that criminals who had escaped his noose were reprieved for the most capricious of reasons.

U.S. distribution by IFC Films
Scheduled to open November 17
www.pierrepointmovie.com

RADIO

3 Psyched!

A weekly program broadcast on Sirius Satellite Radio (LIME, Channel 114). Hosted by *Scientific American Mind* contributing editor Robert Epstein. Guests have included Daniel Gilbert of Harvard and Rosalynn Carter.

877-PSYCHRADIO (877-779-2472)
www.sirius.com

WEB SITES

4 www.doctorhugo.org

Hugo Heyrman is a "Belgian painter and new media researcher" who has put together this highly cerebral site on the aesthetics of mind. For those readers who enjoyed our "Body Language" section this month, take a look at "What human beings tell with their bodies," a series of ultrabrief video loops that clearly show the body language of the inner mental state.

www.swarmsketch.com

The ultimate collaborative artwork facilitated by the Web: "collective sketching of the collective consciousness." You can add your own lines to an ongoing work and vote on lines drawn by other e-artists. Aesthetically the end result resembles the doodles on your (insert boring subject here) notebook at the end of the semester, but knowing that a sketch such as "Mt. Rushmore" was drawn by up to 1,000 people gives it a great philosophical weight.

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

MICHAEL TAYLOR (1); COURTESY OF FIRST RUN FEATURES (2); COURTESY OF ROBERT EPSTEIN (3); WWW.DOCTORHUGO.ORG (4)

SPECIAL REPORT
THE BODY SPEAKS

Hand and arm movements do much more than accent words; they provide context for understanding

Gestures Offer

Our body movements always convey something about us to other people. The body "speaks" whether we are sitting or standing, talking or just listening. On a blind date, how the two individuals position themselves tells a great deal about how the evening will unfold: Is she leaning in to him or away? Is his smile genuine or forced?

The same is true of gestures. Almost always involuntary, they tip us off to love, hate, humility and deceit. Yet for years, scientists spent surprisingly little time studying them, because the researchers presumed that hand and arm movements were mere byproducts of verbal communication. That view changed during the 1990s, in part because of the influential work of psycholinguist David McNeill at the University of Chicago. For him, gestures are "windows into thought processes." McNeill's work, and numerous studies since then, has shown that the body can underscore, undermine or even contradict what a person says. Experts increasingly agree that gestures and speech spring from a common cognitive process to become inextricably interwoven. Understanding the relationship is crucial to understanding how people communicate overall.

GETTY IMAGES

Insight

By Ipke Wachsmuth

The Visual Information Channel

Most of us would find it difficult and uncomfortable to converse for any extended period without using our hands and arms. Gestures play a role whenever we attempt to explain something. At the very least, such motions are co-verbal; they accompany our speech, conveying information that is hard to get across with words. Hand movements can display complex spatial relations, directions, the shape of objects. They enable us to draw maps in the air that tell a puzzled motorist how to reach the turnpike. People who do not gesture rob themselves and their listeners of an important informational channel.

Neurological findings on individuals with communication disorders also demonstrate a fundamental connection between speech and gestures. Brain damage that leads to the loss of mobility in limbs can compromise verbal communication. Patients with aphasia—who do not have the ability to speak or to understand speech—also find it difficult to gesture or understand signs by others. These cases and others suggest that gestures are controlled by the very brain regions responsible for speech.

The interpretations of sounds and movements are closely related for the listener

First date. Her hands might tell him how she really feels: tense, engaged, apprehensive. Or…?

GINA GORNY *Gehirn & Geist*

as well. For years, the link could be demonstrated only indirectly by asking test subjects what information they gleaned from others who were speaking and gesticulating. Recent brain research has provided much better insight. For example, neuroscientist Spencer D. Kelly of Colgate University has studied gestures with the help of event-related potentials—characteristic brain waves consisting of a sequence of peaks and valleys—that occur in certain patterns when one person observes another communicating. The patterns reveal neuronal-processing steps in particular brain regions. One of the negative peaks (a valley), referred to as N400, is especially significant. It occurs when we stumble over an inappropriate and unexpected word, for example, when we hear a sentence like "He spread his toast with socks."

Kelly hooked test subjects to an electroencephalograph and charted their event-related potentials while they watched a video. In it, an actor spoke while using gestures to indicate characteristics of an object. A hand movement might fit a word semantically, such as when the word "tall" was illustrated by gesturing at a long-stem glass on a table. A gesture might also be used to convey additional information, such as when "tall" was accompanied by finger movements that indicated the thinness of the elongated stem of the glass. Viewers saw contradictory scenes, too, in which an actor combined the word "tall" with a gesture that referred to a short object on the table. And sometimes an actor made no gesture at all; in this control situation, the test subjects heard only the spoken word.

Subjects exhibited substantially different brain-wave patterns depending on the situation. The researchers found strong negative peaks—a so-called N400 effect—whenever speech and gesture contradicted one another. They interpreted this phenomenon to mean that gestures and words are in fact processed together: observers factor the meaning of a gesture into their interpretation of a word.

This conclusion was supported by the finding that the event-related potentials exhibited no comparable negativity in the control situation. Even during early processing, the curves differ depending on whether the hand movement fits the word, complements it or contradicts it. "The

(Babies develop **nuanced gestures** between nine and 14 months, yet the spoken word lags behind.)

semantic content" of hand gestures, Kelly says, "contributes to the processing of word meaning in the brain."

Which Came First?

Despite intriguing progress, scientists from various disciplines can still only guess at the origins of the close coupling between gestures and speech. Because primates possess a particularly rich repertoire of gestures—young chimpanzees, for example, typically hold out an open hand when begging from their mothers—it may be that gestures preceded speech in humans. Other researchers advance the notion that "vocal gestures"—simple sounds that could be used as units of meaning, much like hand movements or grimaces—arose first in humans.

Observing young children can provide clues to the common development of oral and visual communication. Up to the age of nine to 12 months, babies reach out with all the fingers of their open hand for whatever object they want—similar to the chimpanzee begging for food. A neuronal maturational shift occurs at about 10 or 11 months in girls, somewhat later in boys: babies begin to point with one finger rather than all the fingers. The effort to get hold of an object is transformed into directed pointing, usually to get the attention of a caregiver. The pointing also usually accompanies a baby's initial attempts at verbal symbolization ("da," "wawa"), even though the early attempts frequently fail. A more nuanced gesturing vocabulary begins to develop as fine-motor finger control improves, between nine and 14 months, yet the spoken word continues to lag behind.

Tabling a Topic with One Hand

Synchronized word-gesture combinations begin to be seen in parallel with the child's developing word usage at 16 to 18 months, ultimately leading to children and adults who "embody" with their hands and arms the shape of an object, how people in a group exercise are positioned relative to one another in space, even abstract and metaphorical thoughts. Put your two palms together, lay them aside your right ear, close your eyes, and lean your head to the side—most people will understand that posture as a symbol for "sleep."

Regardless of whether speech or gestures came first in evolution or which of them develops first in babies, humans have come to rely on many varieties of co-verbal gestures. McNeill, in his influential 1992 book *Hand and Mind: What Gestures Reveal about Thought,* subdivided co-verbal gestures into four basic types: deictic, iconic, metaphorical and beats.

Deictic (pointing) gestures often accompany words such as "here," "there" or "this" and also "I" and "you." In each case, the speaker points to something concrete (*this* table) or to something figurative ("in *this* case"). When people say "I," they often point toward themselves with a slightly open hand. And even when a person points toward herself without saying "I," we generally assume that she is talking about herself.

Iconic gestures express images. These movements may relate to something spatial but also to an event, as when someone says, "Susie chased the cat with an umbrella," while poking about with an imaginary umbrella. Such gestures may provide additional information by depicting more precisely just how the poor animal was chased

Acting Natural

Robotics engineers are interested in nonverbal communication because people will perceive a robot that can effectively mimic the gestures of real people as much more natural. Our team at the University of Bielefeld has created a virtual robot—the Multimodal Assembly eXpert, or Max—that understands and produces co-verbal gestures. If it watches a human being who points at a virtual object and issues the instruction, "Mount that part over there," it can actually carry out the action. Communications with Max are smooth and natural, in part because it understands body language well enough to clear up ambiguities. When I tell Max to go "left" and then point to my left, Max immediately knows that what I mean is "left, from Ipke's perspective"—right, to its perspective. It also simultaneously produces spoken sentences and gestures, which simplifies communication tremendously. Employed at the Heinz Nixdorf MuseumsForum in Paderborn, Germany, Max welcomes visitors there. *—I.W.*

UNIVERSITY OF BIELEFELD

(The Author)

IPKE WACHSMUTH teaches artificial intelligence at the University of Bielefeld in Germany.

Orators know that a well-placed gesture can be the best way to **make a point** hit home.

away—with a stabbing or swatting motion—and whether the cat ran off to the right or left.

Metaphorical gestures look similar to iconic ones but generally relate to abstractions. When we say, "The next topic...," we may define an invisible object with a half-opened hand. The abstraction then seems to move into the real world, where it becomes tangible. But if we then say, "...will be tabled for the time being," we may flatten the hand and place it down onto an imaginary table or even metaphorically sweep the object off the table. Iconic and metaphorical gestures may become just as conventional in their meanings as words; a hand wiping imaginary sweat from one's brow means, "That was a close one!"

Finally, we are familiar with beats from political speeches; the punctuated arm or hand movements that are closely linked with the rhythm of the speech give emphasis to what is being said and apparent power to an argument, regardless of its actual content.

These conventionalized gestures can work without our having to say anything. But McNeill is particularly interested in the connection between spontaneous gestures and the spoken word. That both might stem from the same thought was hypothesized in the 1980s by Adam Kendon, a cognitive scientist and founder of gesture research who now divides his time between the University of Pennsylvania and the University of Naples L'Orientale in Italy. He observed that the so-called gesture stroke of a co-verbal hand sign—the actual conveyor of meaning, such as mopping one's brow—is enacted shortly before or at the latest when its verbal affiliate is enunciated. Whether a cat is being chased away with an umbrella, or a subject is being tabled, the listener is given visual information just before the verbal information.

According to McNeill's theory, the process of speech production and the process of gesture production have a common mental source in which a mixture of preverbal symbols and mental images form the point of origin for the thought that is to be expressed. This growth point, as McNeill calls it, represents a kind of seed out of which words and gestures develop.

Think First, Gesture Later

McNeill also points out that the various language families differ in how they distribute components of meaning between speech and gesture—at least when referring to directional kinds of information. In Romance languages such as Spanish, the gesture stroke is more likely to be coupled with the verb, that is, with "climbs" in "he *climbs* the ladder" (accompanied by the speaker's hand moving upward). In Germanic languages such as German and English, the same gesture stroke is more likely to be used to indicate the locus of action: "he climbs *up* the ladder" (accompanied by an upward hand thrust).

The languages clearly differ in how information about paths is conveyed, McNeill says. His former doctoral student, Gale Stam, now at National-Louis University in Chicago, uses this finding to determine whether a Spanish speaker who is learning English is beginning to think in English. If his gesture stroke continues to fall on the verb "climb" while speaking English, he is probably still thinking in Spanish and thus is purely translating. If the gesture stroke spontaneously falls on the preposition "up," she assumes that the transition to thinking in English has occurred.

The growing appreciation among scientists for the tight interweave between speech, thought and gesture is giving rise to theories about how the brain creates and coordinates these functions. One influential new model comes from psychologist Willem Levelt of the Max Planck Institute for Psycholinguistics in Nijmegen, the

Spaniards vs. Germans

Do southern Europeans really gesture more than northern Europeans? That is the common characterization. Yet "there is absolutely no empirical evidence to back it up," notes Cornelia Mueller, a linguist at the Free University of Berlin and co-founder of the Berlin Gesture Center. In a recent study comparing Spaniards with Germans, Mueller was unable to find evidence that Germans gesture less. Members of each nationality did tend to gesture differently. Germans use their wrists more often. Spaniards use shoulders and elbows more frequently, so "their movements tend to be spatially 'bigger' and are therefore more visible," Mueller says. "This may be why people think they gesture more." —*I.W.*

Now she interprets him: confident, distanced, matter-of-fact?

GINA GORNY *Gehirn & Geist*

Netherlands. According to Levelt, the brain produces a verbal utterance in three stages. First the brain conceptualizes an intended message as purely preverbal information—as a concept that is not yet formulated linguistically. In the second stage, the brain finds words for this concept and constructs sentences—again, a purely internal process. Only in the third stage do the organs of articulation come into play, producing the desired utterance via the lungs and vocal cords.

One of Levelt's students, Jan-Peter de Ruiter, has incorporated gestures into this model. He assumes that the initial conceptualization stage also encompasses a visual precursor for gestures. According to de Ruiter, the brain creates gestural sketches. In the second stage, the sketch is transformed into a gestural plan—a set of movement instructions—that leads to muscle motor programs in the third stage. These programs tell our arms and hands how to move.

This model helps us to understand why gestures may precede the speech they are meant to accompany. The words first have to be assembled into a grammatically sensible expression, whereas the motion is conveyed by standard motor instructions. In a sentence such as "Susie chased the cat with an umbrella," the brain needs time to construct the proper word sequence, which takes longer than issuing the simple motor instruction for "sweep the right arm."

De Ruiter is examining in greater detail the presumed interaction between speech and gesture for pointing motions. He has recorded dialogues between two people telling each other stories and has found that an extended gesture—such as when someone points up toward the sky—tends to delay the verbalization to which it refers ("the plane ascended at a steep angle"). Gestures also adapt to speech; when a storyteller has misspoken and stumbles momentarily, a preprepared gesture appears to be held in abeyance until the speech component is running smoothly again.

These kinds of insights show that understanding how the body communicates is crucial to understanding verbal communication. Spoken words are not the only way humans convey meaning. As professional orators have known for centuries, a well-placed gesture can be the most effective way to make a point hit home. The more we learn about how the body communicates, the better we will become as communicators and observers. M

(Further Reading)

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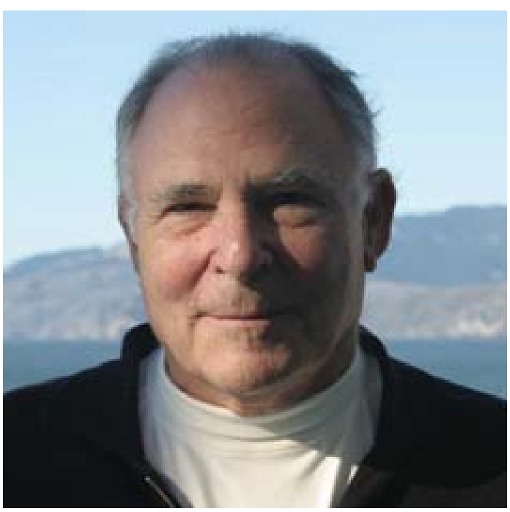
SPECIAL REPORT
THE BODY SPEAKS

A LOOK TELLS ALL

A person's face will always reveal his true feelings—if, like Paul Ekman, you are quick enough to recognize microexpressions

By Siri Schubert



Paul Ekman: Read my face.

COURTESY OF PAUL EKMAN

We do it automatically. As soon as we observe another person, we try to read his or her face for signs of happiness, sorrow, anxiety, anger. Sometimes we are right, sometimes we are wrong, and errors can create some sticky personal situations. Yet Paul Ekman is almost always right. The psychology professor emeritus at the University of California, San Francisco, has spent 40 years studying human facial expressions. He has catalogued more than 10,000 possible combinations of fa-

GETTY IMAGES

cial muscle movements that reveal what a person is feeling inside. And he has taught himself how to catch the fleeting involuntary changes, called microexpressions, that flit across even the best liar's face, exposing the truth behind what he or she is trying to hide.

Ekman, 72, lives in Oakland, Calif., in a bright and airy house near the bay. As I talked with him there, he studied me, his eyes peering out from under bushy brows as if they were registering each brief facial tic I unknowingly exhibited. Does his talent make him a mind reader? "No," he says candidly. "The most I can do is tell how you are feeling at the moment but not what you are thinking." He is not being modest or coy; he is simply addressing the psychological bottom line behind facial expressions: "Anxiety always looks like anxiety," he explains, "regardless of whether a person fears that I'm seeing through their lie or that I don't believe them when they're telling the truth."

The professor calls the ever present risk we all take of misreading a person's visage

"Othello's error." In Shakespeare's drama, Othello misinterprets the fear in his wife Desdemona's face as a sign of her supposed infidelity. In truth, the poor woman is genuinely alarmed at her husband's unjust, jealous rage. Othello's subsequent decision to kill Desdemona is a fatal error, and Ekman wants to make sure that police, security personnel and secret service agents do not make the same mistake. "Arresting the guilty is a good thing," he acknowledges, "but decreasing the number of innocent people who are falsely accused is just as important." His system for understanding the emotions that faces portray, and his expertise in applying it, could help all kinds of law-enforcement and legal personnel in their work. It could also help the rest of us better negotiate how our family members, friends and colleagues really feel.

Expressions can speak volumes, although they are open to interpretation. Is he hesitant, doubtful, concerned?

GINA GORNY *Gehirn & Geist*

Face Code Deciphered

The very fact that psychologists are studying the emotion of facial expressions at all is due in large measure to Ekman's work. When he began studying psychology at the University of Chicago in the 1950s, emotions were a neglected subject at the periphery of the discipline. Many researchers believed that an individual's emotional world was inaccessible to scientific scrutiny—or at least was less interesting than, say, the mechanisms of learning and thinking or the motivations behind human actions.

Ekman, however, was fascinated by the mystery of nonverbal communication. He wanted to understand why some people had little trouble decoding the feelings of others, almost as if they were reading an open book, whereas others fell for one con artist after another. His motto was: trust your eyes, not conventional wisdom. The widespread belief then was that facial expressions arose simply from cultural learning: a child in a given culture learned the faces that accompanied particular emotions by observing people, and over time different cultures developed different expressions. Even renowned researchers such as anthropologist Margaret Mead were unconvinced of the existence of a universal repertoire of expressions, as Charles Darwin had proposed in his book *The Expression of the Emotions in Man and Animals,* published in 1872 but subsequently ignored.

To test his own hunch, Ekman headed for Brazil with a stack of photographs in his suitcase. The portraits showed sad, angry, happy or disgusted faces of white Americans, yet Brazilian college students had no trouble identifying the feelings depicted. Expeditions to Chile, Argentina and Japan generated the same results; regardless of where he went, local people seemed to understand, and use, the same facial expressions as the North Americans.

Concerned that perhaps inhabitants of "modern" societies had somehow cross-pollinated their facial movements, Ekman in 1967 visited extremely isolated tribes living in the jungles on the island of New Guinea. There again, though, he found that the basic emotions he had postulated,

> People in America, Chile, Japan and New Guinea **share expressions** for anger, surprise and disgust.

such as happiness, sadness, anger, fear, surprise and disgust, were associated with universal facial expressions. The excursion sealed it for him: the language of the face has biological origins, and culture has no significant effect on it.

This recognition raised a whole new set of questions. How many different facial expressions are human beings capable of? What precisely does a particular expression signify? Is it possible to learn how to read emotions? Ekman decided to create a sort of common dictionary of facial expressions, and he set about doing so with a mixture of meticulousness and daring.

"If I had known how long it would take to set up such a system, I might never have begun," he says now, with a slight sigh. "At the time, we didn't even know whether a person can make the same expression twice—whether his expressions always differ, even if only in minor ways."

Perceiving Microexpressions

Ekman and his U.C.S.F. colleague psychologist Wallace Friesen spent six years formulating their Facial Action Coding System (FACS), which they published in 1978. The system makes it possible to describe and classify any facial expression based on a combination of 43 facial-action units [*see box on next page*]. The 43 elements yield more than 10,000 possible combinations. Ekman and Friesen catalogued each combination by a FACS number, the Latin names for the muscles involved and the associated emotion, if any. For example: "1; inner brow raiser; frontalis, pars medialis," is one element of sadness.

One interesting aspect of this inventory is that many muscle combinations signify absolutely nothing. Ekman discovered another interesting phenomenon after spending the day in his laboratory trying to reproduce a convincing look of sadness: that evening he realized that he was feeling depressed. He then found that if he spent time engaged in imitating the components that make up a smile, his mood lifted. "That was like an epiphany," he recalls. It contradicted the naive notion that feelings originate solely in the psyche and that the body merely communicates them outwardly.

Ekman and Friesen were able to demonstrate that the coordinated tightening of certain facial muscles not only affected blood pressure and pulse rate but also could trigger the corresponding emotion. It seemed clear that a feedback mechanism was at work between the facial muscles and the brain's emotion centers.

Such a linkage caught the attention of psychologists, and by the early 1980s FACS started to be applied to real-world situations. Practitioners wanted to know how they might ascertain whether their patients were telling the truth by watching their faces. Such a talent could be critical, as an old videotape Ekman had made proved. The tape showed a psychiatric patient named Mary, who, apparently recovered from a severe bout of depression, begged her treating physician to allow her to spend the weekend at home. The doctor approved her request, but luckily before leaving, Mary admitted that she had planned to commit suicide.

Ekman had already studied the tape; he told viewers that if facial expressions indeed unveil a person's true feelings, they should be able to read Mary's intentions. Most viewers did not see the telltale sign at first, so Ekman pointed it out. He originally had watched the video over and over, often in slow motion so as not to miss even the slightest detail. And suddenly he saw it: for the briefest moment, a look of sheer desperation could be seen flitting across Mary's face. Such microexpressions—which often last no more than a fifth of a second—were the key. Regardless of how stoic we try to look or how heartily we laugh off a situation, the control that we can exert over our own facial features has its limits. Our true feelings always leak out, even if only for an instant.

When he discovered microexpressions, Ekman was teaching at U.C.S.F., and he spent several years putting together a self-teaching program that enabled people to decode faces according to the FACS system. By paying close attention to microexpressions, people can learn to read signals that previously would have been perceptible only in slow motion. And here Ekman hit

(The Author)

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Regardless of how stoic we try to look, the control we can exert over our facial features has limits.

on another interesting phenomenon: most people—including law students, police officers, judges and prosecuting attorneys—find it difficult to expose fakers, but a small number of people seem to be able to correctly interpret microexpressions intuitively. Apparently, some of us are born with handy lie detectors.

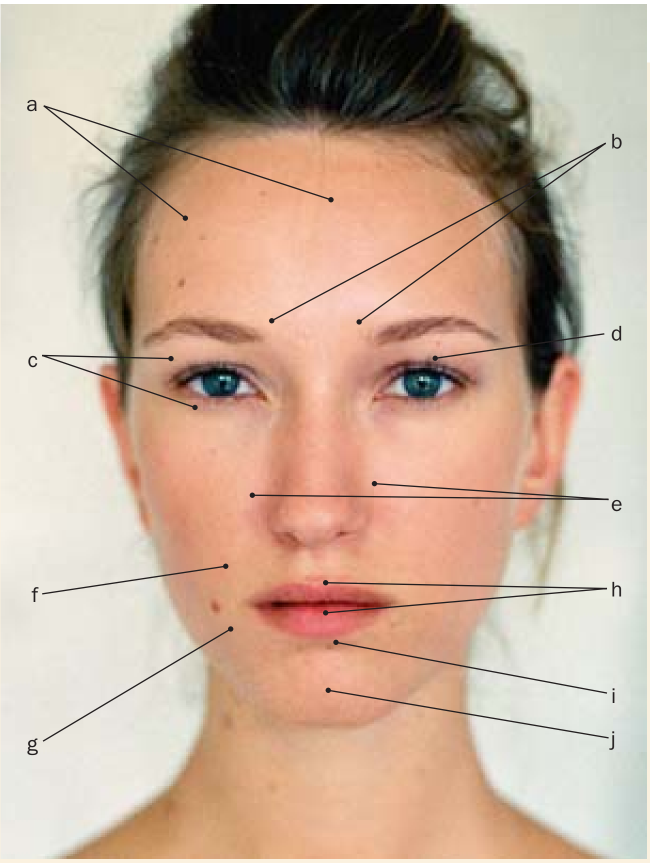
This capability should make more than a few fibbers—kids, criminals and politicians among them—very uneasy. On the other hand, certain individuals can learn to be convincing prevaricators. "Think of a chess player who controls his emotions and sets his facial expression so the other player will interpret it in a certain way," Ekman suggests. In addition, the more an individual believes his or her own fabrications, and the more often he or she serves them up successfully, the more difficult it will be for others to see through the deception. "Lies that are being told for the first time and that have an emotional component are the easiest to expose," Ekman says. That is why he recommends that interrogators ask their questions quickly and with an element of surprise. For example, instead of asking, "Were you in the parking lot of the Wal-Mart yesterday evening at six o'clock?" it is better to ask, "Where do you usually buy household items?"

Hard Truth

Although it is possible to learn to recognize microexpressions, Ekman warns against using them as a clear-cut indicator of a lie. Whenever he trains security personnel, he emphasizes the importance of asking a suspect how what the person just said made him or her feel. The response will make it less likely that an investigator will commit Othello's error. In addition, questioners need to pay attention to details other than facial expres-

Decoding Faces

In the 1970s Paul Ekman and Wallace Friesen developed the Facial Action Coding System, a tool kit for describing human facial expressions that can also reveal their emotional content. The system defines the contraction of individual facial muscles as so-called action units and assigns an emotional correlate to each one. For example, contraction of the orbicular eye muscles (*c*) accompanies every true smile. Contraction of the levator labii superioris alaeque nasi muscle (*e*) indicates disgust. Although there are 43 action units, robots and animated beings can reproduce many lifelike expressions using these two and eight others: the frontal muscles (*a*), corrugator muscles (*b*), eyelid muscles (*d*), zygomatic muscles and lifters (*f*), depressor anguli oris (*g*), orbicularis oris (*h*), depressor labii inferioris (*i*) and mentalis (*j*). *—S.S.*



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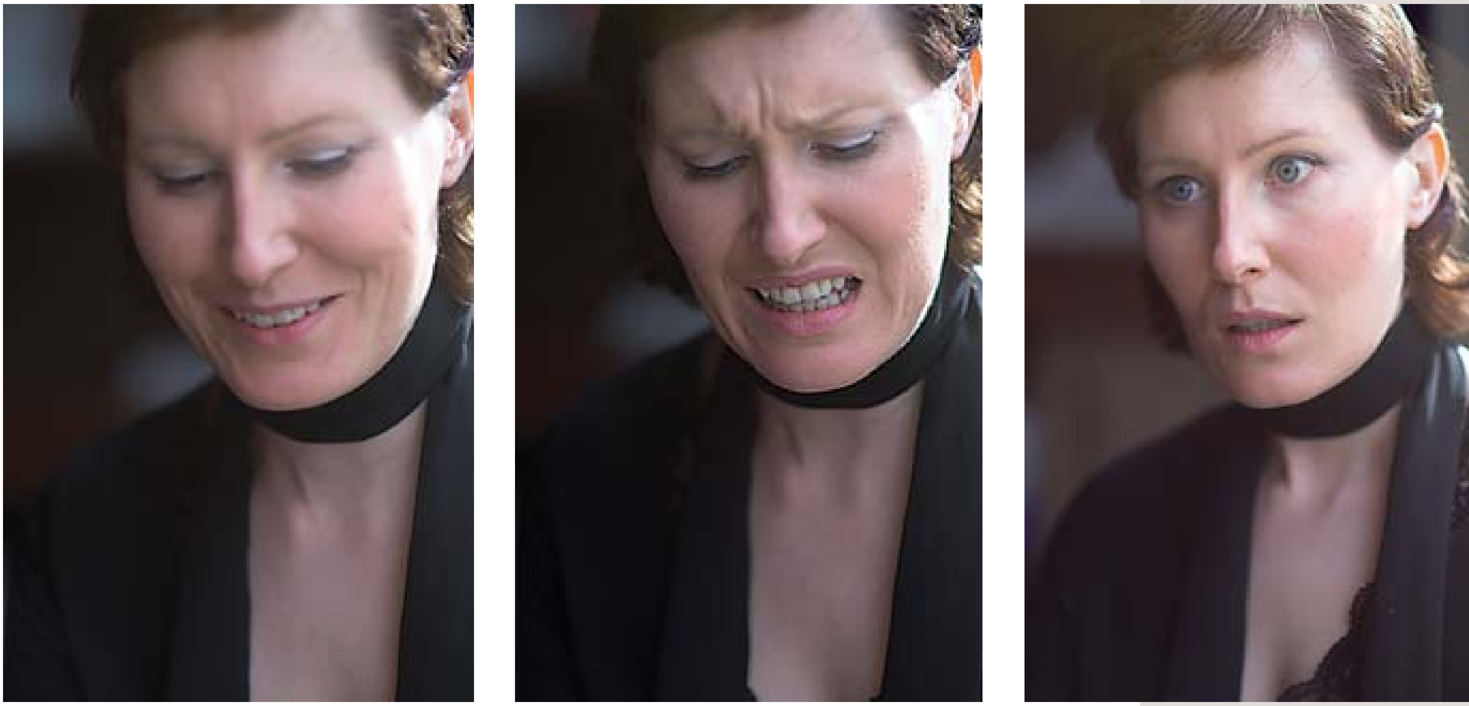

Sometimes emotions seem clear: happy, disgusted, surprised. Or is she smiling nervously, perhaps pained, feeling confronted?

sion, such as small shifts in posture, speech or hand gestures, all of which could indicate a fabrication [see "Gestures Offer Insight," by Ipke Wachsmuth, on page 20]. Unless the suspect is Pinocchio, there is no unambiguous proof of a lie.

As to why so many people find it difficult to recognize deception, Ekman says, "Many people simply want to believe what they are being told, even if they really know better. Who wants to find out that your spouse is being unfaithful with your best friend? Or that your kids are using hard drugs? You should want to, but it's terrible when you discover it. And if you knew this, you'd have to do something about it; most of us are pretty avoidant."

From an evolutionary perspective, it would not necessarily have been advantageous for humans to be perfect lie detectors. In small, close-knit groups, little falsehoods are frequent and help group members gloss over unimportant mishaps or inequities. If every lie was singled out, the resulting confrontations would almost certainly do more harm than good. In the end, the smooth talkers would probably be expelled from the group, weakening its number if nothing else, and none of those remaining would have gained any benefit from the expulsion.

When it comes to hunting down terrorists, however, the ability to unmask has real survival implications. Ekman spends a great deal of time training antiterror specialists, even though he has been retired for over two years. Nevertheless, he is well aware of the narrow scope of his methods. "The tools I have to offer are pretty modest," he notes.

He also sees parallels between his work and that of the Dalai Lama, whom he has met several times at conferences. Like the spiritual leader, Ekman wants to help people understand their own feelings and master their impulses. "The only area where I differ with the Dalai Lama is on the issue of reincarnation," he muses.

Before we end our discussion at his home, I ask him about his own relationship to the truth. Ekman considers the question for a moment. "I have a golden rule," he responds, "according to which I decide when a lie is permitted. I ask myself how the other person would feel if he found out that he had been lied to." If the person would feel betrayed or taken advantage of, then the lie would be damaging.

Vigilantly offering the truth at every daily interaction and social occasion, though, may be of little value. "Would you tell your hosts that you were bored out of your mind at their party?" Ekman asks. "You see, no one would expect that—not even from an expert on lying." M

(Further Reading)

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GINA GORNY *Gehirn & Geist*

SPECIAL REPORT
THE BODY SPEAKS

Exposing LIES

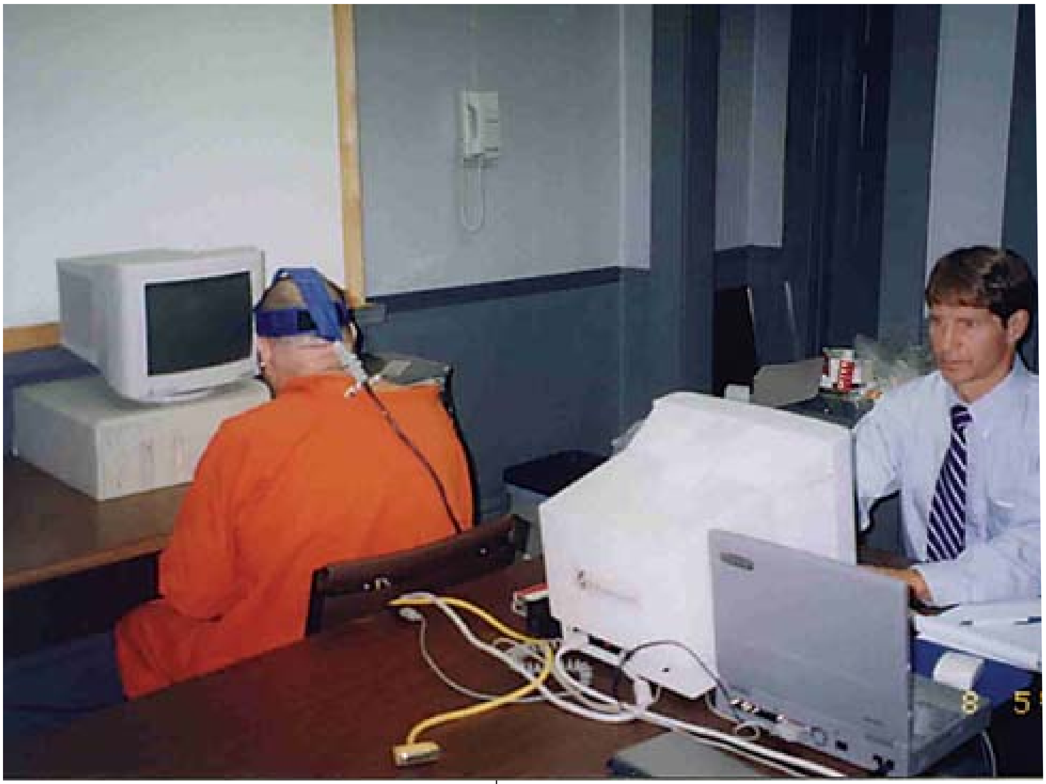
Inventors claim that new technologies can ferret out fibbers, but it is unclear what the gear actually reveals

By Thomas Metzinger

The body does not lie. So stated William Moulton Marston, a psychology professor who devised components for the polygraph and in 1938 published *The Lie Detector Test*. Marston and his co-inventors maintained that regardless of how well a person could control his voice and face, other signs such as blood pressure, heart rate, respiration and skin conductivity would betray him when he told a lie. The physiological changes, they said, were triggered by the anxiety an individual feels when he knows he is fabricating information. Marston's own work with the machine convinced him that women were more trustworthy than men, and he went on to champion the female's role in society, in part by creating and writing the comic strip "Wonder Woman" (who wielded a "truth lasso," among other gadgets).

The trouble with the polygraph, scientists found later, was that a person could become anxious simply by being hooked up to the machine and even more so when asked probing questions. After years of controversy, evidence gleaned from lie detectors remains inadmissible in most courtrooms.

STEWART COHEN *Getty Images*



Lawrence A. Farwell administers a "brain fingerprinting" test to murder suspect James Grinder in 1999. Brain waves sensed by the headgear showed that Grinder recognized information flashed on a screen related to details of the 1984 murder that ostensibly only the perpetrator would know. Grinder later pled guilty.

BRAIN FINGERPRINTING LABORATORIES, INC.

Undeterred, today's inventors have devised a second generation of equipment that senses signals inside the brain and body, which the creators say provide clear evidence of lying. Tests are under way to determine whether any of these schemes is reliable all the time. Although the results are not clear-cut, it seems inevitable that sooner or later governments or courts will allow a new kind of test result to be used as evidence in trials. Given the pace of innovation and its potential payoff—identifying terrorists, convicting criminals and reducing the number of innocent people wrongly sentenced to prison—neuroethicists are playing catch-up. They must find some fast answers as to whether mental clues picked up by machines can actually expose a person's true intentions and whether any part of our inner minds should be considered private and inviolable.

Content from Carrier

All lie detectors operate on the basic assumption that a person who intentionally says something untrue is conscious of doing so. The new techniques further posit that a physical correlate must exist for the subjective experience of knowingly lying—a pattern of neuron activation or some other physiological sign.

Identifying such a correlate is problematic, however. Imagine that a Martian visits us, picks up some chalk and writes a series of symbols on a blackboard. The chalk marks are the physical carrier through which the alien is attempting to convey his message. But what are the symbols' contents—what do they mean? To the Martian, everything—but to us, nothing. Many philosophers maintain that researchers who are attempting to read thoughts are merely defining the carrier—the neuronal pattern on which a thought is riding—but not the content; the researcher will never be able to tell us what the message means, much less whether the messenger is lying.

But the current inventors argue that there may not be a meaningful difference between the carrier and the content of a thought. They say empirical studies of how the brain represents information indicate that carrier and content may be one and the same. These researchers cite modern theories of mental representations that suggest that information processing in the neuronal network is subsymbolic and not rule-based—meaning that, unlike a computer, the brain does not follow a rigorous syntax. Mental content actually takes the form of the strength of connections among myriad neurons; it is directly reflected by the physical structure and dynamics of the synaptic gaps that connect neurons in a network. Mental content is indeed the physical carrier.

Caught in the Act

The new lie detection schemes exploit this point of view. The working theory is that as soon as a person intentionally lies he is conscious of doing so and that a neuronal correlate exists for that consciousness. The challenge is defining what the correlate is. The approach closest to commercialization comes from Lawrence A. Farwell, who calls his technique brain fingerprinting and runs a company called Brain Fingerprinting Laboratories in Seattle.

Suppose French police have just boarded an American airliner that has landed in Paris, on the suspicion that the crew are CIA agents who had abducted several Afghan citizens and taken them to a secret detention center. To determine if this is the case, the French investigators place a helmet on a suspected agent's head. The helmet contains electrodes that record a person's brain waves on an electroencephalogram (EEG). The investigators then show images to the suspect: some of random items, some of the missing Afghanis, some of recognizable CIA offices and some of the purported detention center. According to Farwell, if the crew member sees an image of something he has already seen in real life, a specific brain wave known as P300 will arise. Neuroscience studies have shown that P300 occurs when the brain recognizes information as familiar. Thus, if the suspected agent falsely says he does not recognize a missing Afghani or the detention center, a P300 wave will appear on the machine's recording.

Critics of brain fingerprinting say that anxiety, as well as alcohol or drug use, can adversely affect the P300 correlation. They also note that if the crew members were indeed CIA agents who had seen simple mug shots of the missing people or photographs of the detention center, those images alone would be enough to raise the P300 wave indicating familiarity but certainly not be indicative of guilt.

Nevertheless, the real CIA and FBI have given Farwell a good deal of funding. He maintains that the P300 wave is a very reliable indicator of whether a respondent is being truthful. Like Marston and the polygraph, Farwell says that a guilty person would possess a mental representation of people or objects related to a crime in ways that no other person would harbor. Of course, that means interrogators must find such evidence and prove its novelty.

Field tests of brain fingerprinting are under way. The apparatus figured prominently in an Iowa court's 2003 reexamination of a case involving Terry Harrington, who had been convicted of murdering a security guard in 1977 and had spent 25 years in prison. When hooked up to the machine, Harrington's brain did not react to items that the killer certainly would have known. Partly as a result of this evidence, the state's highest court reversed his conviction and set him free.

> (The theory is that a person is **conscious of lying**, and neuron activation patterns reveal that consciousness.)

Other technologies are equally compelling and controversial. Psychiatrist Daniel D. Langleben of the University of Pennsylvania has developed a "guilty knowledge test" based on magnetic resonance imaging. Deliberate lying, he says, shows up on scans as a particular neural correlate in the anterior cingulate gyrus as well as part of the left prefrontal cortex, regions of the brain that are associated with mental representations of conflict. Langleben claims that the scientific problems involved in optimizing his lie detector are solvable. But his procedure has one operational drawback: subjects must be prepared to cooperate and stay motionless inside a scanner during interrogation.

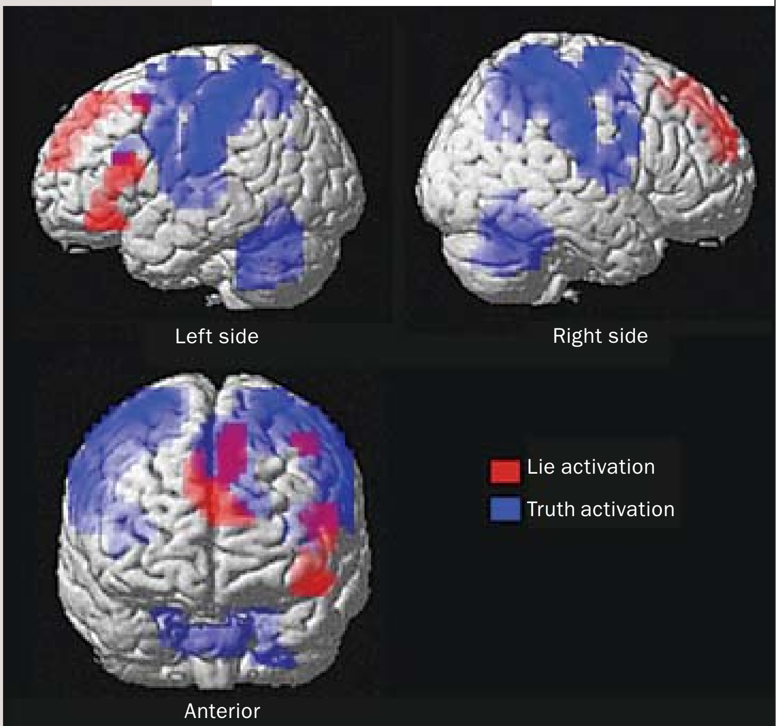
Some psychologists have raised a fundamental objection to Langleben's procedure: even if the method can detect a mental conflict, they say, it cannot detect its resolution. There is no way to tell if the subject is experiencing a conflict because he is lying or merely because he is considering whether or not to lie.

Another University of Pennsylvania professor, biophysicist Britton Chance, has focused on a different brain property. He has fashioned a headband that sends near-infrared light into the skull and captures its reflection. Chance says the sensors can detect changes in the prefrontal cor-

(The Author)

THOMAS METZINGER is professor of philosophy at Johannes Gutenberg University in Mainz, Germany, and is president of that country's Cognitive Science Society.

(Empathy, prejudice and aggression can be traced to neuron patterns, but does that **prove guilt** of a crime?)



Different brain regions are active when individuals tell the truth (*blue*) and when they lie (*red*). The average activity for 22 people examined with fMRI by psychiatrist Daniel D. Langleben of the University of Pennsylvania is shown.

tex—the site of decision making—that occur when a person decides to lie. The device is still in development.

James A. Levine, an endocrinologist at the Mayo Clinic in Rochester, Minn., is working with heat-sensing cameras that can detect a rush of blood to the face, particularly around the eyes, that occurs as a person tells a lie. Such a noninvasive, easily applied technology could be handy for rapidly screening people—for example, at airport security gates. But the technique is preliminary, and its accuracy remains an open question.

Paul Ekman, professor emeritus of psychology at the University of California, San Francisco, is working on a lie detector based on microexpressions—tiny changes in facial expressions that most people cannot deliberately control [see "A Look Tells All," by Siri Schubert, on page 26]. But Ekman has said he is not interested in his method being applied to judicial proceedings, because it cannot provide 100 percent accuracy.

Fatal Flaws?

Whether any of the technologies can be considered foolproof remains to be seen. Psychology professor J. Peter Rosenfeld of Northwestern University is among the sharpest critics. One fundamental flaw, he notes, is that the contents of memory change over time. Furthermore, many people, in particular those who are mentally retarded or addicted to drugs, do not store memories accurately or recall them reliably.

Rosenfeld and others also say that investigators can easily influence how subjects react to P300 tests, merely by using emotionally laden language during questioning. University of South Florida psychologist Emanuel Donchin adds that P300 waves are very sensitive to the order in which stimuli are presented and that the subjective decisions about questions that police must necessarily make during interrogations would compromise test results. Donchin, who used to work with Farwell, also says false positives are likely. For example, the brain of a person who sees a green sweater and responds with a P300 wave is not necessarily reacting because he had seen the murder victim wearing the garment; the same effect could arise if the suspect had recently seen a similar sweater in a store window, marked down to a very affordable price.

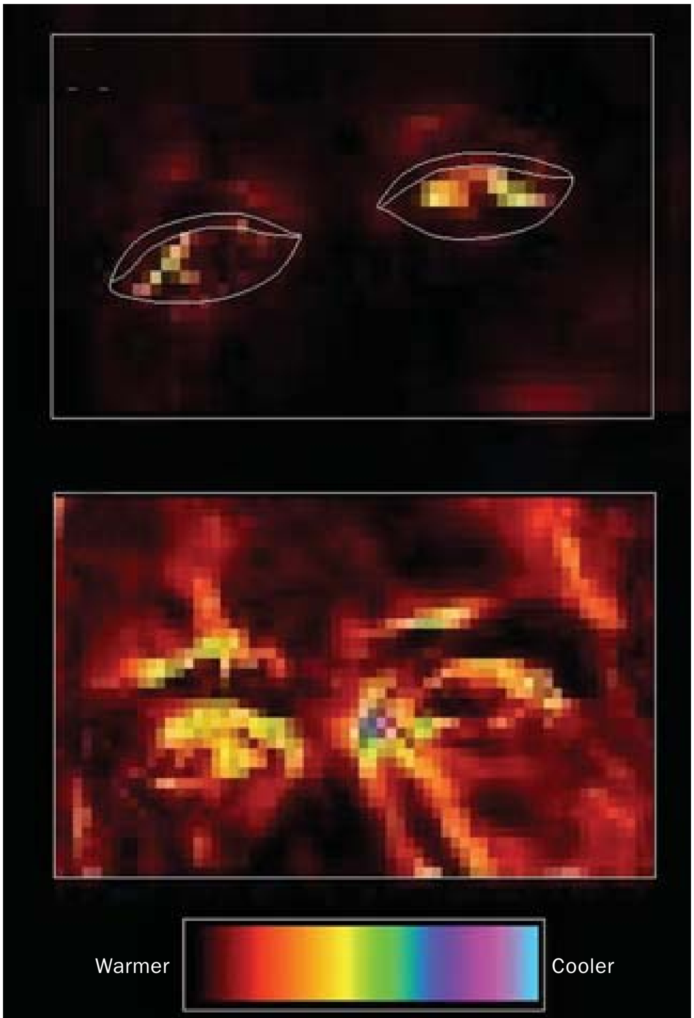
Paul Root Wolpe, a psychiatry professor and fellow of the University of Pennsylvania Center for Bioethics, points out that the 170 or so "scientific tests" that Farwell cites as support for the reliability of brain fingerprinting refer not to separate studies but to individual research subjects, all of whom were tested by Farwell himself. So far Farwell has not permitted independent researchers to confirm his results. Wolpe also worries that premature commercialization of any of these techniques will thwart the basic research that still needs to be done to prove them and could undermine their long-term credibility if they appear faulty in early applications.

Ethics Needed

Assuming one technology does demonstrate its accuracy, a second question arises: Is using it ethical?

This question might first arise in connection with criminal trials. Just as the improving science

SOURCE: "CLASSIFYING SPATIAL PATTERNS OF BRAIN ACTIVITY WITH MACHINE LEARNING METHODS: APPLICATION TO LIE DETECTION," BY C. DAVATZIKOS ET AL. IN *NEUROIMAGE*, VOL. 28, NO. 3, PAGES 663–668; NOVEMBER 15, 2005



Blood rushes to the eyes and face when a truthful individual (*top*) knowingly lies (*bottom*), according to heat-sensing cameras operated by endocrinologist James A. Levine of the Mayo Clinic.

IOANNIS PAVLIDIS *Honeywell Laboratories* AND NORMAN L. EBERHARDT AND JAMES A. LEVINE *Endocrine Research Unit, Mayo Clinic*

of genotyping led courts to allow DNA evidence to help determine the guilt of defendants, attorneys are already trying to introduce methods of "brain typing" into court. Neuroethicists would be well advised to start working on the issues now.

Already lawyers are attempting to use brain science to characterize an individual's personality—notably whether someone accused of a violent crime has an inborn tendency toward aggressive behavior. A person's capacity for empathy, degree of neuroticism, even unconscious racial prejudice are other examples of psychological traits that can be traced to certain patterns of brain activity. But do these traits, if provable, bear on a person's potential to commit, or culpability in, a crime?

On a societal scale, use of accurate lie detectors could have far-reaching consequences for people's private lives. First we must define privacy as it pertains to the brain. Should our inner mind be inviolable, a place that must not be invaded? Do mental representations constitute a private domain that the police and security agencies have no right to enter? That stance might be a tough limitation for criminal law, where guilt often revolves around the intent of the perpetrator.

If mental representations are off-limits, neuroethicists must balance this view against the potential social good that lie detectors could provide: helping to defend people and nations against terrorists, preventing false accusations and convictions against the innocent, simplifying investigations, and protecting society from potential criminals.

Lie detectors could create a more transparent society, too, which would strengthen democratic culture. Imagine that the leading candidates running for president had to appear on a televised debate, but this time a big red light in front of each politician would turn on when a scanner sensed that the candidate was telling a premeditated lie. "Political openness" would take on new meaning.

Society must also consider its assumptions about personal autonomy: Would we as citizens be willing to lose some freedom in exchange for security if in principle we could no longer hide anything from the government? What would it mean if such resistance tactics as lying or refusing to answer questions were no longer possible? Would simply knowing about the existence of sophisticated lie detectors change our mental lives? Before the technology advances any further, we will need some answers. M

(Further Reading)

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AHA!

The Eureka Moment

We've all had sudden, smart insights. How do they arise? And is there a way we can conjure them up at any time?

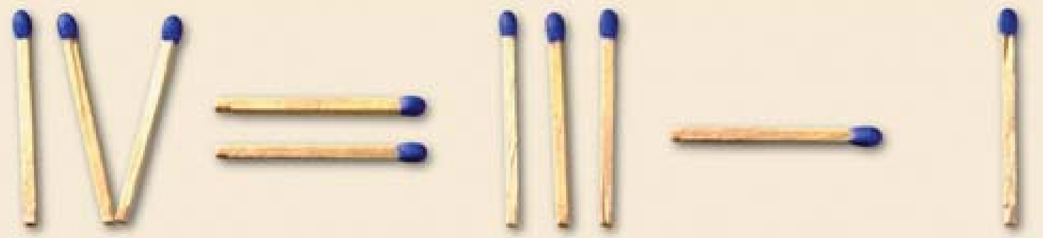
By Guenther Knoblich and Michael Oellinger

Albert Einstein finally hit on the core idea underlying his famous theory of relativity one night after months of intense mathematical exercises. He had given himself a break from the work and let his imagination wander about the concepts of space and time. Various images that came to mind prompted him to try a thought experiment: If two bolts of lightning struck the front and back of a moving train at the same time, would an observer standing beside the track and an observer standing on the moving train see the strikes as simultaneous? The answer, in short, was no. The floodgates in Einstein's mind opened, and he laid down an ingenious description of the universe. With his sudden insight, Einstein turned our conceptions of time and space inside out.

BILDAGENTUR-ONLINE

Puzzle One

Simple thought experiments can create pleasing "Aha!" moments—when you discover the answer yourself or when you give up and view the solution. The equation shown is obviously incorrect. To create a valid equation, you can move only one matchstick once (but not remove it). Only Roman numerals and the three operators +, –, = are allowed.



The solution appears on page 42.

> Apparently the **unconscious processes** that lead to insight tend to take place in the right hemisphere.

Certainly Einstein would not have reached his brilliant notion without his vast knowledge of physics and his ability to think clearly. But the decisive moment arose from his capacity to imagine physical reality from a perspective no one else had ever tried. Einstein was a master at restructuring problems.

We all know how it feels for a solution to a tough problem to suddenly appear in our mind. The chips fall into place, the lightbulb goes on—and the answer seems so obvious that we are amazed we had not noticed it sooner, which is what creates the "Aha!" feeling. But what happens in the mind to produce this eureka moment? The answer could help all of us be consummate creators.

Knowledge Can Hinder Discovery

Researchers looking for that answer face a daunting methodological problem: how to enable volunteers to systematically produce insights for investigation. The experience is quite subjective. A new point of view arises from an unconscious shift in perception, and the elements of the problem metamorphose into a solution.

Such insights have nothing in common with a computer's step-by-step method of solving problems. They are haphazard. Nevertheless, Janet Metcalfe, a psychology professor at Columbia University, devised one way to capture the leaps of understanding. She encouraged volunteers to wrestle with insight problems and asked them while they were thinking to announce periodically whether they were "warm" or "cold"—feeling closer to, or still far away from, a solution. She found that even a second before individuals had eureka moments, they felt just as cold as they had at any other time during the endeavor.

If insights feel utterly unintentional, then what brings us to the right idea, if it is not the power of our willful thinking? Psychology professor Stellan Ohlsson of the University of Illinois at Chicago thinks we begin approaching a problem by creating a mental representation of it—a kind of inner model—that includes only certain salient features. At first, we try to look at the features through the lens of our previous experience, which is natural. Yet our very knowledge can prevent us from seeing the features in a new light. Our thoughts go around in circles. We become frustrated. We waste time reapplying methods we already know to be futile. We get nowhere.

Ohlsson believes this mounting failure is precisely what drives us to restructure a problem. The increasingly tense stalemate initiates unconscious processes that change our mental representation of the problem. We look at the features through a

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new lens. Suddenly, novel possibilities emerge.

The belief that prior knowledge hinders problem solving invokes a bit of a dilemma, however. Taken to its limits, it means that people who possess the least possible knowledge are in the best position to crack a case. Note that it was Einstein, steeped in complex physics, who hit on the theory of relativity, not a contemporary from another discipline, such as Sigmund Freud. Yet although knowledge and experience in the problem area are indispensable, they can be a hindrance if they become so fixed that they block new ideas. Successful experiments begun as early as the 1920s by Gestalt psychologists Karl Duncker and, later, Abraham Luchins demonstrated that habitual use of familiar objects and problem-solving strategies limits the ways individuals employ them.

In 1998 psychologist Jennifer Wiley, then at the University of Pittsburgh, revived this work with a new study investigating the relation between expertise and blindness to alternatives. In one test she gave subjects three words and asked them to find a single, fourth word that would combine with each of three initial words, creating reasonable concepts. For example, given "knife," "blue" and "cottage," they could add "cheese"—as in cheese knife, blue cheese and cottage cheese.

Half of Wiley's subjects were chosen because they indicated they considered themselves to be experts on baseball. The other half did not. Wiley gave the group three words, one of which would combine with the added, common word to create a well-known baseball term. The volunteers saw "plate," "broken" and "rest" and were expected to come up with "home" as the matching word: "home plate" (the baseball term), "broken home" and "rest home."

Wiley then started a second test, presenting the words "plate," "broken" and "shot." This time the target word was "glass," which yielded "plate glass," "broken glass" and "shot glass." The baseball experts had more trouble with this second set of terms than the nonexperts. Apparently the aficionados had become so fixated on the term "plate" because of their affinity for "home plate" that it was harder for them to break free of that construct and come up with "glass" for "plate glass." Their knowledge blocked fresh creative insight.

Taking a Novel Perspective

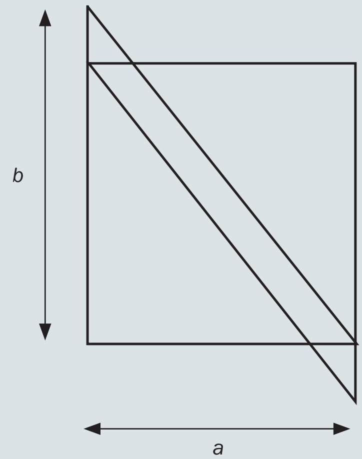
A related question is whether existing knowledge can prevent a person from creatively defining where the solution to a problem might lie. This parameter is perhaps the most important mental factor in setting the stage for reaching a eureka moment.

To study this notion, we created several kinds of tests. In one case, we set up arithmetic problems and gave them to volunteers to solve. We spelled out a mathematical equation on a computer screen, using virtual matchsticks to form the Roman numerals and operators (+, –, =) in an incorrect equation, such as IV = III – I [*see box on opposite page for an example*]. Our subjects were to envision a solution in which only one matchstick moved to create a correct equation. They then pressed a button when they thought they had figured out the answer. They found certain problems easy to solve, but others proved considerably harder. The reason, we deduced, was an unconscious block imposed by existing knowledge.

The participants, like most of us, learned in school that solving arithmetic problems is a matter, above all, of manipulating quantities. Most subjects began by moving only the matchsticks that changed the numbers, for example, by taking away the first matchstick forming the "one" in the Roman numeral IV, changing it to V. This strategy worked with certain problems but failed for others. In the failed cases, the problems could

Puzzle Two

The diagram shows a square and a parallelogram superimposed on it. Two dimensions are given: *a* and *b*. The task is to determine the sum of the areas of the two shapes. Even if you have forgotten the formulas for area, try to determine how a full solution could be found—if it can be, given only *a* and *b*.



The solution appears on page 43.

(The Authors)

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JOACHIM HOLLATZ *Gehirn & Geist*

(A nap, an ice cream cone or a ping-pong match can help the brain **see a problem** from a different angle.)

be solved only by moving a matchstick that changed an operator, for example, by taking away the top matchstick in =, leaving a minus sign. The ingrained knowledge that the operators of an equation should remain unchanged brought most of our participants to a standstill. Only when they changed their perspective about where the solution might lie did they open up new possibilities for solving what had seemed to be an intractable problem.

We also measured the eye movements the subjects made while working. At the outset, they looked longer and more often at the numbers, paying almost no attention to the operators. Once they realized that a problem seemingly could not be solved by manipulating the quantities, their eye movements typically slowed. Some people would stare at the same spot on the screen for five to 10 seconds, whereas normally their eyes changed fixation points about three times a second. These people were staring into a blind alley.

We could tell successful problem solvers from unsuccessful ones merely by analyzing their gaze patterns. Those who stared longest at the numbers failed. Those who looked longer at the operators figured out the answer sooner or later—even though they, too, felt at some point that the problem was impossible. The success rates and gaze times both provided evidence for the idea that insight comes about through unconscious processes.

The Right Hemisphere Solution

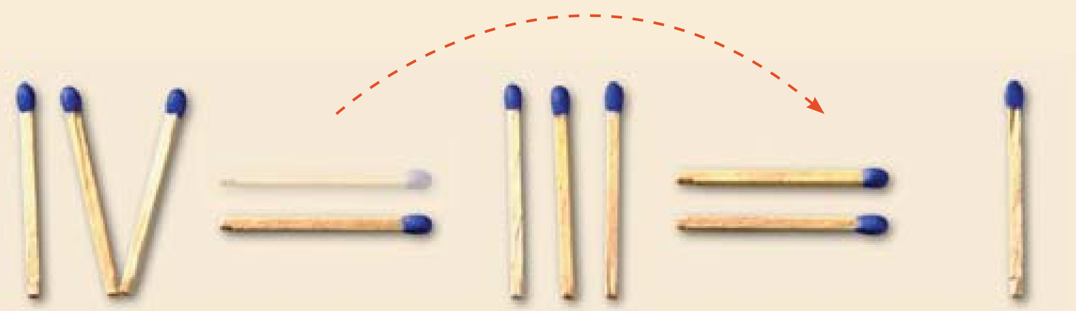
Researchers are also examining the brain's structures to learn how we reach insights. This work is difficult because the standard instruments of cognitive neuroscience, such as electroencephalography and functional magnetic resonance imaging, measure neuronal processes that last from a few milliseconds to a few seconds. Solving problems often takes minutes or hours. Furthermore, many different cognitive processes are in play at once. Investigators therefore use indirect methods to infer which brain regions help to restructure problems and generate insight.

Cognitive neuroscientists Mark Jung-Beeman and Edward Bowden of Northwestern University recently probed the question of whether both halves of the brain are equally involved. For most people, the left hemisphere is primarily responsible for conscious processing of speech, and the right hemisphere takes care of the unconscious perception of space. (Recent research has shown that this crude division varies for many people, but some partitioning of labor does seem to exist.)

Jung-Beeman and Bowden assumed that step-by-step problem solving took place mainly in the left hemisphere, through the conscious application of logical rules, which would rely on deliberate language. The right hemisphere, they figured, played a critical role in solving insight

Solution One

Most people try to fix the equation shown on page 40 by moving a matchstick that changes the numbers, because most of us are taught in school that solving math problems is all about manipulating quantities. Such "knowledge," unfortunately, can blind us to creative insights. The solution lies in moving one matchstick to change the operators, as shown.



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problems, which require restructuring—a spatial task. Individuals would experience a eureka moment only when the right hemisphere sent the solution to the left hemisphere, thereby putting the solution into discernible terms.

To start, subjects had to try to solve various insight problems. The scientists recorded which exercises each person failed to solve. They then exploited the fact that the left eye sends its images to the right hemisphere and the right eye to the left hemisphere. They sat each subject in front of a computer and controlled which eye could see the screen. They briefly flashed the solution to an insight problem the person had failed. Sometimes the solution was shown only to the right eye, sometimes only to the left eye. The subjects perceived the solutions much more frequently when they were seen by the left eye and thus the right hemisphere. Apparently the unconscious processes that lead to insight tend to take place in the right brain.

Sleep and Good Cheer

As investigators learn more about what is happening in the brain during the exact moment of insight, all of us will want to know what we can do to maximize the conditions that allow us to have brilliant thoughts. Clinically proven advice might be a while in coming. Yet anecdotal work suggests that some simple steps can raise our chances.

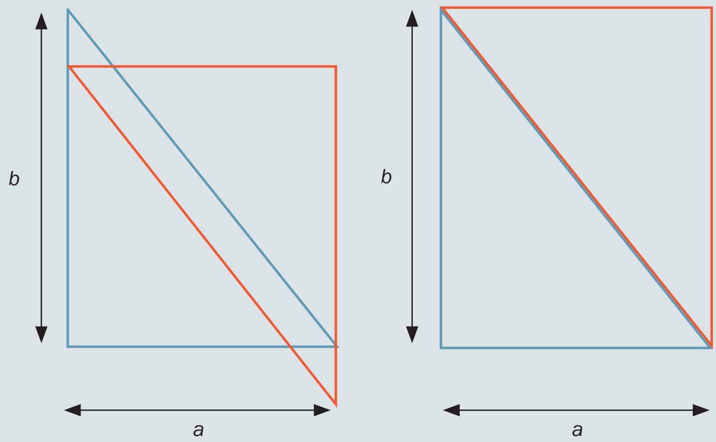
You do have to start with sufficient knowledge to solve your problem. Without it, Einstein would not have succeeded. Then, if you have indeed been working on a problem for a long time and are stuck, get away from it. Take a break. A nap would be even better. Many studies have shown that important insights come in dreams or daydreams or follow short naps. The famous example often cited is of German chemist Friedrich August Kekulé von Stradonitz, who in the late 1800s is reported to have said he discovered the round shape of the benzene ring after working in the lab for hours, then dreaming of a snake swallowing its own tail. Commercial production of benzene sparked the rise of the fossil-fuel industry.

Neuroendocrinologist Ullrich Wagner of the University of Luebeck in Germany has demonstrated that sleep promotes insight. He gave subjects number sequences and two logical rules for manipulating them. But the sequences could also be solved by using a simple "hidden rule" that the test takers might discover as they worked. The examinees practiced problems and were then told to take a break before they had discovered the trick. Some slept during the interlude, and others did not. When they returned to do more problems, the individuals who had slept found the hidden rule much more often than subjects who had not. Wagner attributes the improvement to a process of consolidation of information that takes place in the hippocampus during sleep; new data are connected with knowledge already in memory.

If you cannot take a nap during the workday, it is often helpful to let your thoughts wander. Or break away briefly and do something that puts you in a good mood—have an ice cream cone or play ping-pong. Plenty of research has shown that a positive attitude helps the unconscious brain look at a problem from a different angle, improving your chances of solving it. M

Solution Two

Many people readily see that it is easy to find the area of the square but fail this test because they become fixed on how to determine the area of the parallelogram, concluding that just having *a* and *b* is not enough information. To solve the puzzle, you must look at the problem, literally, from a different angle: the figure can be seen as two right triangles, as highlighted. If the red triangle is moved up, as shown, the pair creates a rectangle, whose area is simply *a* times *b*. Aha!



(Further Reading)

- **An Eye Movement Study of Insight Problem Solving.** Guenther Knoblich et al. in *Memory & Cognition,* Vol. 29, No. 7, pages 1000–1009; October 1, 2001.
- **Sleep Inspires Insight.** Ullrich Wagner et al. in *Nature,* Vol. 427, pages 352–355; January 22, 2004.
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Dogs understand "fetch" and "leash," whereas apes can combine words into short sentences. So what special skill did humans bring to the language game?

Can We Talk?

GETTY IMAGES

By Annette Lessmoellmann

Poetry, perfumed love notes, intimate e-mails and late-night phone messages have been the choice forms of communication for humans in love. Stags, on the other hand, have to rely on a simple, full-throated roar to convey their desire. True, the stag's primitive bellow is effective—smitten females approach while rival males look for cover. Likewise the cries of dogs, cats and birds all serve these animals well as simple forms of communication.

Even so, it does not take a degree in linguistics to realize that a massive gulf in complexity exists between a male deer's amorous cry and "How do I love thee? Let me count the ways." Not surprisingly, then, humans have long felt a sense of superiority as the planet's only masters of language arts. But for scholars of language evolution, this apparent singularity was a source of confusion. If other animals can roar, bark or squawk but cannot talk—or do anything remotely similar—then the many characteristics required for language appear to have evolved in humans from almost nothing.

Increasingly, though, studies of animal communication are chipping away at this feeling of human linguistic supremacy. Scientists are finding that our fine-feathered and furry friends have far more sophisticated communication skills than we give them credit for. Physical and cognitive traits once thought to be uniquely human have been discovered throughout the animal kingdom, suggesting that the rudiments of language have deep evolutionary roots. By studying the ancestral building blocks of language, researchers are finally homing in on what truly unique human traits allowed our language skills to bloom and flourish.

Not all that feeling of human pride at our way with words was sheer bravado. It was also backed up by some scientific observations. Biologists once thought, for example, that humans were the only mammals whose larynx was capable of producing different vowels. Even our cousins the chimpanzees cannot voice vowels, because their vocal apparatus is too plump. In addition, they are unable to control their breath with sufficient precision to appropriately aspirate sounds.

Indeed, every textbook on the subject proclaimed that the human larynx was a key example of how humans were specially adapted for language—or at least books made such claims until about 2001. That is when bioacoustician W. Tecumseh Fitch of St. Andrews University in Scotland and David Reby, now at the University of Sussex in England, were able to demolish this myth by finding an animal whose larynx is anatomically similar to its human counterpart and is capable of producing a wide variety of sounds—the deer. Our friend the stag may not be a poet, but he is capable of much more than just a simple roar.

So other animals might have vocal machinery sophisticated enough for speech. But without the right cognitive abilities, the roaring, singing and cheeping of the animal world, however vocally complex, would not be much more than noise. For example, the ability to create categories was thought to be a talent reserved for humans. Only *Homo sapiens* could group such different beings as a dachshund, a Doberman and a Pekingese into a single, abstract category and word: "dog." These kinds of abstractions obviously play a prominent role in language.

> (If animals cannot talk or do anything similar, human language appears to have evolved from **almost nothing**.)

Here, too, research findings have undercut the notion of a pedestal with a single language-capable species on top. Behavioral biologists have found that macaques, chinchillas and even birds divide their world into rational units. Japanese quail, for example, can learn to group sounds that are similar in certain ways into categories, even if they do not use words to describe them.

And although animals do not spontaneously use words, they can demonstrate an uncanny ability to understand them. In 1999 viewers of a European TV game show were treated to a remarkable display of verbal know-how as they watched Rico, a border collie, fetch the right toy—when given a name—out of a collection of 77 playthings. This feat meant the animal understood words such as "teddy bear" or "piggy." "An awfully ambitious woman trained her dog very well," thought Juliane Kaminski of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, when she first heard of the performance. Skeptical that Rico actually understood these words, she invited the black-and-white spotted pooch into her laboratory.

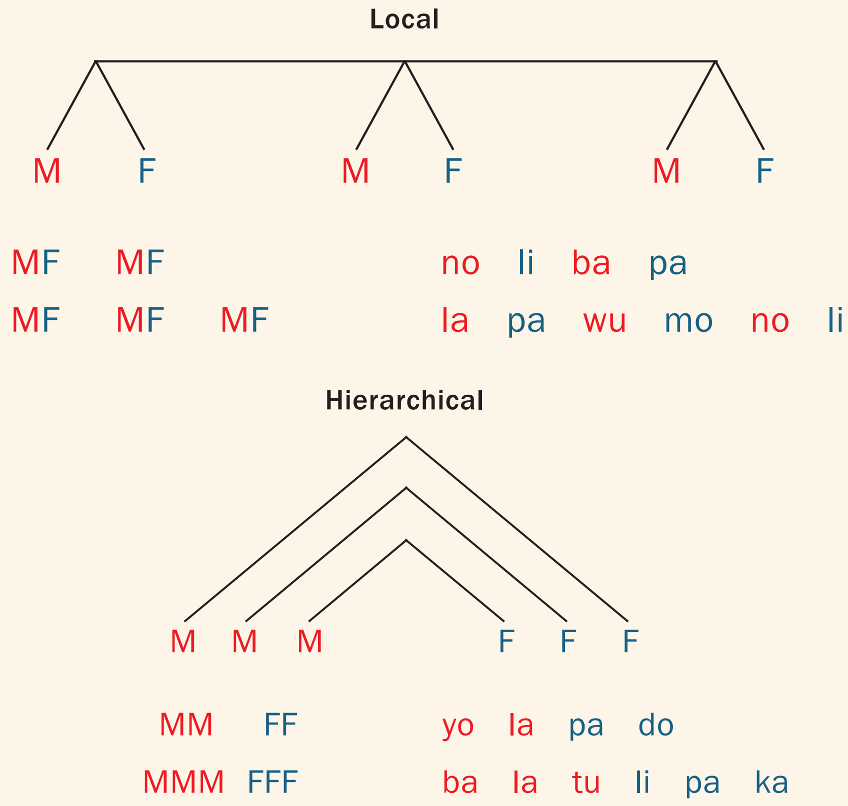
The results of her study appeared in 2004 in the journal *Science*. At the beginning of the test, Rico already knew 200 words. To make sure the dog was directly responding to the words themselves and not some other cue, the investigators took two precautions. Rico's mistress was prevented from providing him with any winks or signals and the objects were not visible when their names were called out. Yet when asked, the

Grammar for Monkeys

To test the listening skills of humans and animals, researchers invented artificial grammars composed of simple sequences of sounds. The syllables in blue were spoken in a female voice (F) and all the red ones by a male (M). This experiment simulates a language consisting of just two different categories (such as nouns and verbs).

The upper row follows the rules of a simple grammar: after an M comes an F; after an F comes an M. So M and F are only locally dependent on each other.

Below is a more complex, hierarchical grammar. The first M depends on the final F, and between these two an infinite number of MF pairs can be nested within one another.



GEHIRN & GEIST

dog fetched the black teddy bear, even if the toy was located in an adjacent room.

Kaminski and her colleagues were especially impressed by how easily Rico learned. For example, sometimes the researcher hid an unknown toy behind her back, along with several familiar ones. Then she said a new word to the dog. Rico immediately went over to the objects, picked up the new thing—and remembered its name for the next time.

Of course, Rico did make mistakes now and again, "but so do kids," Kaminski comments. In her opinion, the collie operates at about the level of a three-year-old child in terms of language comprehension.

The Talkative Animal Farm

But it was a bonobo named Kanzi and his kin who finally gave even the most skeptical observers reason to believe that when it comes to language, humans ought to get off their high horse. Sue Savage-Rumbaugh, a biologist now at the Great Ape Trust of Iowa, began in the 1970s to teach apes words with the help of pictograms.

Young Kanzi was an especially eager student. He can use up to 200 "words" by pointing to a display, and he understands twice that number. But the bonobo—today a quiet adult in his mid-twenties—can do far more than merely point to a picture of a banana when he is hungry. He also understands how to string various images together, connecting their meanings. Sometimes he combines a "word" with a specific gesture and thus creates sentences.

His half sister, Panbanisha, also showed herself to be gifted in language. She once excitedly pressed her finger down on three images, one after another, again and again: "fight," "mad" and "Austin," the name of another chimp in Savage-Rumbaugh's big troop. The researchers later discovered that two animals had been beaten in Austin's part of the compound.

All this work suggests that instead of human

(The Author)

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Turning heads: Faulty grammar catches the attention of cotton-top tamarins, if the rules are made simple enough.

KEVIN SCHAFER *Corbis*

language appearing from thin air, many of the prerequisites for it may have existed—and still do exist—in many species. So why are humans so much more sophisticated in their use of language? Consider, for one thing, the incredible number of words and their meanings that we can process mentally. The average native English or German speaker can recognize about 30,000. This capability is only latent for many people, because they can understand these words in context but do not use them all in their own writing or speech. But the vocabulary is there to be activated—and expanded—at any time. Even the best wordsmiths among dogs and chimps have a vocabulary less than 1 percent as large.

But the really important differences are not just a matter of quantity, according to Marc D. Hauser, professor of psychology at Harvard University. "The secret lies in the grammar," he says. The decisive trait that makes human language different from animal abilities is the complexity of sentence structures that we employ and understand.

The thinking goes that no other animal, including nonhuman primates, can create nested sentences such as "The woman, whose dress, which was not unattractive, and rustled when she walked, sat down next to me." Even the clever bonobo in Iowa would be lost at "The woman, whose dress rustled ..." In short, relative clauses are a human prerogative. This point of view is not new. In the 1950s linguist Noam Chomsky of the Massachusetts Institute of Technology first formulated the idea that human language is hierarchically structured, permitting upper and lower levels to exist.

Determining whether or not animals can process such complex grammatical structures is not easy, however, given that the most accomplished beasts still have relatively simple vocabularies. But recently psychologists and brain researchers have discovered a clever way to test this hypothesis in monkeys.

Say "Ba, La, Tu"

Whereas the precise notion of a clause may be impossible to explain to a monkey, the simple rule that governs its usage does not require understanding the meaning of words at all. For example, the relative clause rule works this way: when you see a term such as "the woman," then you can attach a relative clause to it. This clause rule is how statements such as "The woman, whose dress rustled when she walked" arise. After the insertion of this clause, the sentence with "the woman" as its subject may continue: "The woman, whose dress rustled when she walked, sat down next to me." Now the relative clause rule may be applied to the newly inserted clause, and so on: "The woman, whose dress, that her husband, whose brother ..." It is only our feeling for style and the limits of our working memory that prevent us from adding clauses ad infinitum. It is not impossible, however.

Hauser studied how monkeys would deal with similar, nested structures. Together with Fitch, he confronted cotton-top tamarins (*Saguinus oedipus*) with an artificial language composed of meaningless syllables such as ba, la, tu, pa, ka [*see box on preceding page*]. These New World monkeys are known for being able to recognize spoken sounds and for having a remarkable sense of rhythm. The animals are able, for instance, to distinguish spoken Dutch from Japanese.

The researchers played the animals tapes of syllables, spoken either by a male (M) or a female (F) voice. In addition, the syllables were clearly divided into two groups, so that the female voice always read different syllables from those read by the male. All this was designed to allow the tamarins to easily distinguish the elements from one another. Then Hauser and Fitch used these syllables to create two artificial grammars. One consisted of the simple rule that male and female voices must alternate—for example, the series MFMFMF. The other "language" grammar was more complicated and capable of nested patterns: an M must be, sooner or later, followed by an F. This leads to more challenging sequences such as MMFF (representing the nested structure M[MF]F) or even MMMFFF (M[M[MF]F]F). The initial sound thus opened a door that had to be, at some later time, closed by an appropriate final sound.

Human speakers know this rule, too. They know that a sentence beginning with "if" needs to be followed by a "then" (even if it is only implied)—completely independently of how much additional material is inserted between these two elements. And when tested, human subjects could detect violations in both the simple and complex invented grammars. The researchers wanted to see whether monkeys conditioned to examples of one rule would subsequently recognize violations of this rule. They noticed that their subjects would suddenly stare at the speaker who made a sound. Hauser and Fitch measured the length of the gaze the tamarins directed at a speaker to judge whether violations of the rule caused them to pause longer.

Hear No Rhythm

The animals stared longer at a speaker when the simple grammar was violated. On the other hand, inconsistencies in the more complex grammar left them cold. After hearing structures similar to MMMFFF, the animals reacted no differently when something like MMMFFM was played. They were not able to recognize complex, nested structures, so they could not detect any violations. But Hauser and Fitch did not go so far as to state that the monkeys understood anything even about the simple grammar. "The tamarins probably did not grasp the rules explicitly," Hauser says. "They could, though, distinguish between known and unknown sequences."

So the monkeys lack the understanding of structures that many linguists consider the alpha and omega of language competency. To investigate why people can identify these patterns and nonhuman primates cannot, Angela Friederici of the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig put human subjects in MRI machines and played tapes of Hauser and Fitch's grammars.

She found that the subjects processed the different sequences in different areas of their brains. Simple MFMF structures were processed by the frontal operculum on the lower end of the primary motor cortex. This region is old from an evolutionary perspective, because other primates possess it as well. Its job is to make reasonable predictions about what should come next in sequences, although the precise way the operculum works has never been studied, Friederici says. "That [region] could be important for grasping musical rhythms, as well as for complex utterances."

But complex, nested sequences or rhythms appear to be beyond this part of the brain. When the subjects in the MRI scanner listened to the complex MMMFFF sequence, it was not the operculum that reacted, but Broca's area instead. This area exists only in humans and is responsible for understanding language. Apparently it is also the place where nested structures are analyzed.

If Friederici, Hauser and Fitch are right, then the ability to process this type of structure may mark a crucial division between human and animal communication. When our ancestors' brains developed the ability to process nested structures, they were suddenly able to explore, improve and diversify their communication in complex new ways. It was as if they discovered a music or a grammatical rhythm in the world to which every other creature was tone-deaf. And ultimately that may have given humans a great deal to talk about. **M**

> (The trait that makes human language different is the **complexity** of sentence structures that we employ.)

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Verbal Bottleneck

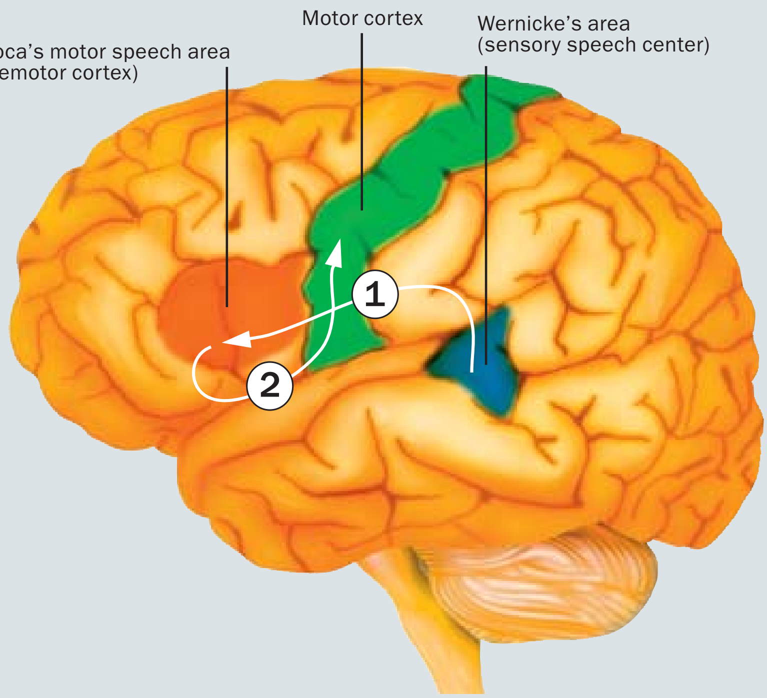
People who stutter sometimes suffer from mistaken notions about their intelligence or emotional balance, but the problem is the neurophysiological process of speaking itself

By Katrin Neumann

Greg K. was only three when the problem began. During a family vacation he saw two crashed cars burning. Soon after that, his parents recall, the boy began stuttering. Even today, at the age of 40, Greg is more likely to order lasagna in a restaurant and forgo his favorite pizza, capricciosa, because he cannot manage words that begin with explosive sounds like the letter "k."

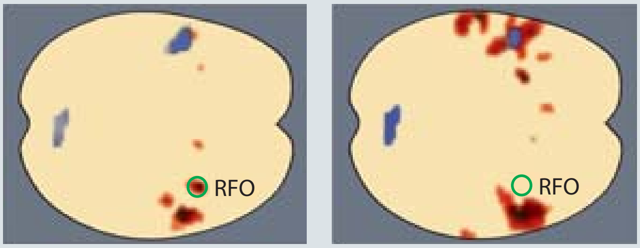
Speaking is precision work, yet most people merely have to open their mouths and a well-ordered flow of words pours out. In scant milliseconds, the brain coordinates our speech apparatus so that it makes all the appropriate sounds. The muscles of the larynx, tongue and lips work in unison, while air is metered out in exactly the right amounts. But for the approximately 1 percent of all individuals who stutter, verbal communication requires more than a little willpower.

The Speech System



NORMAL PROCESS

The individual steps involved in speech production occur in a precise sequence. Broca's motor speech area in the lower left frontal lobe (*orange*) sets the process in motion and transmits sound units to be spoken into speech motor programs. The motor cortex (*green*) then directs the organs of articulation (*arrow 2*), such as the larynx or the tongue. During speech, constant self-monitoring occurs (*arrow 1*) via auditory areas like Wernicke's area (*blue*).



BEFORE AND AFTER THERAPY

Before treatment (*left*), a stutterer's brain exhibits comparatively more activity (*red*) in the right hemisphere, particularly in the right frontal operculum (RFO). In contrast, less activity (*blue*) occurs in the areas of the left hemisphere that relate to speech. Broca's motor speech area is particularly affected, a clear indication of functional weakness in this area. Accordingly, stutterers compensate for the left-sided speech center deficit by way of the RFO.

After therapy (*right*), the left hemisphere demonstrates increased activity. Areas close to Broca's speech motor area and other speech motor centers are particularly active during speech (*red*). Therapy participants are able to speak almost fluently immediately after treatment. The lower level of activation in Broca's speech motor area persists (*blue*). In general, the brains of those who have undergone therapy activate considerably more during speech, because maintaining the newly learned speech patterns requires constant monitoring.

SIGANIM *Gehirn & Geist*; MATTHIAS KULKA *Corbis* (*preceding pages*)

> Most stutterers can recite poems or sing with relative ease but conversation can be distressing.

Whereas some people view stuttering as a personality disturbance or even as a sign of low intelligence, the difficulty lies in the act of speaking itself. Most stutterers can recite poems or sing with relative ease, but normal conversation can be a distressing exercise in frustration.

The disorder usually appears between the ages of two and four, is four times more common in males than in females, and often runs in families—genetics may be responsible in 60 percent of cases. Emotion and stress may also influence the onset and durability of stammering. In recent years, researchers have untangled the related neurophysiological mechanisms as well.

Lazy Tongue?

Speculation about the causes of the speech impediment has been widespread since ancient times. Greek philosopher Aristotle, for example, declared that the tongue was the main culprit. He said that it was too lazy to keep pace with the human imagination—a mistaken belief with remarkable staying power. As late as the mid-19th century, physicians were using surgery to correct supposed defects in the tongue.

During much of the 20th century, stuttering was seen as a neurotic tic and a sign of deep psychological conflicts, thanks to Sigmund Freud and his successors. In this view, sufferers were trying to express suppressed desires. Still others suspected that it represented a form of learned anxiety behavior, provoked by the unsympathetic and angry reactions of listeners.

Undoubtedly, environmental surroundings can play a significant role. Young children who unself-consciously utter the staccato bursts of sound at home may find themselves the target of teasing when they enter nursery school. As a result, they may come to avoid talking as much as possible, which only increases their social inhibitions and isolation.

Greg K. finds it painful to recall his teen years. Tongue-tied and with low self-esteem, he struck out with the in-crowd and in his attempts to make friends with girls. Military service was a nightmare: during roll call, the recruits had to shout out their names. Greg hardly ever delivered his with the crispness required—and his surname begins with the dreaded "k" sound.

Halting speech becomes more pronounced under stressful conditions, like face-to-face conversations. Conversely, fluency stabilizes if the stutterer is relaxed or when an external pacemaker—such as the rhythm of a poem or song—ensures calm and order. Words may bubble up smoothly when the person is speaking to an infant or a pet or while he or she is asleep.

Compounding the problem, many stutterers suffer from secondary symptoms. As they struggle to spit the words out, they may make faces and gesticulate, breathe in and out deeply, blush or start to sweat. Unfortunately, most people react with irritation to such so-called parakinesis, which makes matters worse. When they interrupt, the stutterer's fear of speaking increases, and the person may withdraw in a huff.

Brain Barrier

Neuroscientists began to explore how neurophysiological problems contribute to the disorder in the early 20th century. Neurologists Samuel Orton and Lee Travis did groundbreaking work in the 1920s that is still considered significant. Both men had observed that left-handed children experienced speech rhythm difficulties whenever they tried to write with their right, or nondominant, hand. Orton and Travis blamed defective lateralization: the brain fails to establish precisely which hemisphere is responsible for what function, resulting in neuronal-processing errors that affect articulation.

Modern imaging techniques support Orton and Travis's idea. During the mid-1990s, positron-emission tomography (PET) demonstrated that stutterers exhibit less activity in the speech centers of the left hemisphere and in certain auditory areas than nonstutterers do, reported Peter T. Fox of the University of Texas Health Science Center at San Antonio and others. At the same time, the corresponding areas of the right hemisphere seemed to be unusually active.

A few years later a German and Finnish team headed by neurocognitive researcher Riitta Salmelin of the Helsinki University of Technol-

(The Author)

KATRIN NEUMANN is an ear, nose and throat physician specializing in voice, speech and pediatric hearing disorders at the University of Frankfurt, Germany.

Stutterers exhibit **structural weaknesses** in the brain's speech motor centers and auditory areas.

Julia Roberts, Carly Simon and James Earl Jones manage their stuttering.

ogy in Finland added precision to these findings. Using magnetoencephalography (MEG) to record the weak magnetic fields that form and continually change as a result of neuronal electrical activity, the investigators found that signal transfers among speech centers in the left hemisphere were occurring in the wrong sequence. The cause was presumably defective neuronal connections.

Another contributor to stuttering is flawed sound processing. Understanding speech is critical for proper speech production [*see box on page 52*]. The so-called Wernicke's area in the cortex of the left hemisphere, which is involved with language comprehension, together with the rest of the auditory cortex, gives us constant feedback on whether our spoken words sound correct. The sounds we hear are constructed into meaningful words and sentences, and their correct articulation is planned in Broca's area, in the lower left frontal lobe. The nearby motor cortex then activates the necessary muscles in the tongue, larynx and lips.

Stutterers may be unable to perceive their spoken words correctly, suggest Janis and Roger Ingham of the University of California, Santa Barbara, and Peter Fox. According to their PET studies published in 2003, Wernicke's area seems particularly affected, as are other areas of the brain responsible for hearing.

Last, stutterers exhibit structural weaknesses in the brain's speech motor centers and auditory areas. In 2001 neuroanatomist Anne L. Foundas of Tulane University observed abnormal fissures and size relations in areas of the cerebral cortex. In addition, in 2002 neuroscientists Christian Buechel of the University of Hamburg and Martin Sommer of the University of Göttingen in Germany discovered that stutterers' nerve fibers were significantly altered in one area below the speech motor cortex. The researchers used diffusion tensor imaging, which detects slight changes in neuronal connections.

Compensating in the Brain

Despite these deficits a fair number of stutterers exert some control over their handicap. Their brains naturally seem able to compensate for the flaws to some extent, and they improve further when aided by therapy [*see box on opposite page*]. This balancing out appears to happen spontaneously as a result of the increased brain activity that occurs in the right hemisphere during speech. Using the scanning technique called functional magnetic resonance imaging (fMRI), our team, including physicist Christine Preibisch of the University of Frankfurt and neurophysiologist Anne-Lise Giraud of the École Normale Supérieure in Paris, identified increased activity in one area, called the right frontal operculum (RFO). The RFO is located in the lower frontal lobe of the right hemisphere and corresponds to the position of Broca's area in the left.

Normally people seem to use the RFO when they recognize grammar mistakes and correct them or when they are called on to understand sentences with gaps. In contrast, the brains of stutterers apparently use the region to restore lost function because of their left-sided deficit. And indeed, the less our test subjects stuttered, the more we saw evidence that neurons in the RFO were firing.

What mechanism switches on when a stutterer learns to speak still more fluently with the help of treatment? To answer this question, our team in Frankfurt joined forces with psychologist Harald A. Euler of the University of Kassel and with Alexander Wolff von Gudenberg, director of the Kassel Stuttering Institute. In the 1990s these two researchers developed a modified version of the American precision fluency shaping program. With the so-called Kassel stuttering method, clients learned a new, softer way of speaking and a special breathing technique. Even two years after treatment, stuttering incidence remained some 70 percent lower in more than three quarters of participants compared with baseline values.

We undertook an fMRI study at the same time to determine exactly what happened in those participants' brains. We documented the

JEFFREY R. STAAB *CBS/Landov* (*Roberts*); EVAN AGOSTINI *Getty Images* (*Simon*); NANCY KASZERMAN *Zuma/Corbis* (*Jones*)

Therapies that Work

The earlier any treatment for stuttering begins, the better its odds of success. Whereas adults often make do with temporary fluency improvements after therapy, programs that start in childhood frequently can eliminate the speech impediment for good.

Numerous options are available to treat communication and speech disorders. Only a few of these, however, have been thoroughly researched. Two methods have proved particularly successful.

In the first, called stuttering modification therapy, stutterers learn what is called pseudostuttering: they are instructed to stutter on purpose, which lets them confront their tics in such a way that they come to no longer fear them.

Fluency shaping, the second method, teaches stutterers new speech techniques. The Lidcombe program, a type of behavioral therapy developed in Australia that is custom-tailored to each child, is one variation. Another was developed by German researchers Harald Euler and Alexander Wolff von Gudenberg; it is a modified version of the precision fluency shaping program created by Ronald L. Webster of the Hollins Communication Research Institute. This treatment begins with a three-week period of intensive therapy in which stutterers learn a new speech pattern. They practice techniques such as stress timing, soft voicing, and smooth transitions between sounds and breathing. Follow-up exercises continue for a year. The long-term successes are impressive: more than two thirds continued to speak significantly more smoothly even after two years.

"Indirect" forms of therapy can help bolster chances for success as well. They focus on educating the parents of stutterers and on helping them to change how they talk to their children. For example, parents learn to avoid speaking rapidly and not to use overly complex sentence structures. *—K.N.*

brain activity of right-handed male stutterers as well as that of a control group both before and immediately after treatment [*see box on page 52*]; we also followed up two years later.

At the outset of therapy, overall brain activity in the stutterers was somewhat higher than that of nonstutterers. As expected, the effect was particularly marked in the right hemisphere and specifically in the right frontal operculum. We also noted decreased activity in the left hemisphere's speech motor cortex and in Broca's area, supporting earlier work.

After therapy, however, the situation changed. During speech, the increased brain activity migrated to the left side, close to the speech motor cortex, Broca's area and the auditory cortex. With speech therapy the brain creates a more successful mechanism of compensation. The question is, did such therapeutic approaches actually "repair" the original speech centers that were less active in the first place? The answer is, unfortunately, no. Rather the surrounding regions made up the processing difference; the areas that were less active at the start of the study continued to fire at about the same rate.

Thus, stutterers' brains naturally attempt to shore up their weaknesses by leaning on the RFO or, after therapy, by using the surrounding regions of the left side's speech and auditory centers. This theory is supported by the observation that people who stutter only slightly usually exhibit more brain activity in the RFO than do severe stutterers, whose brains have been more successful at bypassing their sluggish areas.

In addition, the increased activity in the right hemisphere subsided to a certain degree in stutterers two years after their Kassel-method treatments ended. Their stuttering increased slightly at the same time. We interpret the overall generally higher brain activity in those who have had therapy as a sign that the new speech pattern has to be constantly monitored and practiced and is not completely automatic.

My research is now focusing on how effective, lifelong compensation works in the brain. One of the questions that interests me is how the brain-activity patterns of people whose childhood stammering has subsided differ from those of people who continue to stutter. While researchers like me continue the search for answers, one thing is certain. The earlier one recognizes the signs of stuttering and the sooner therapy begins, the better the chances of long-term success at correcting it. **M**

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THE ELECTRICAL BRAIN

Most nerve cells use messenger chemicals to communicate. Now science is learning more about the brain's rarer, lightning-fast electrical signaling

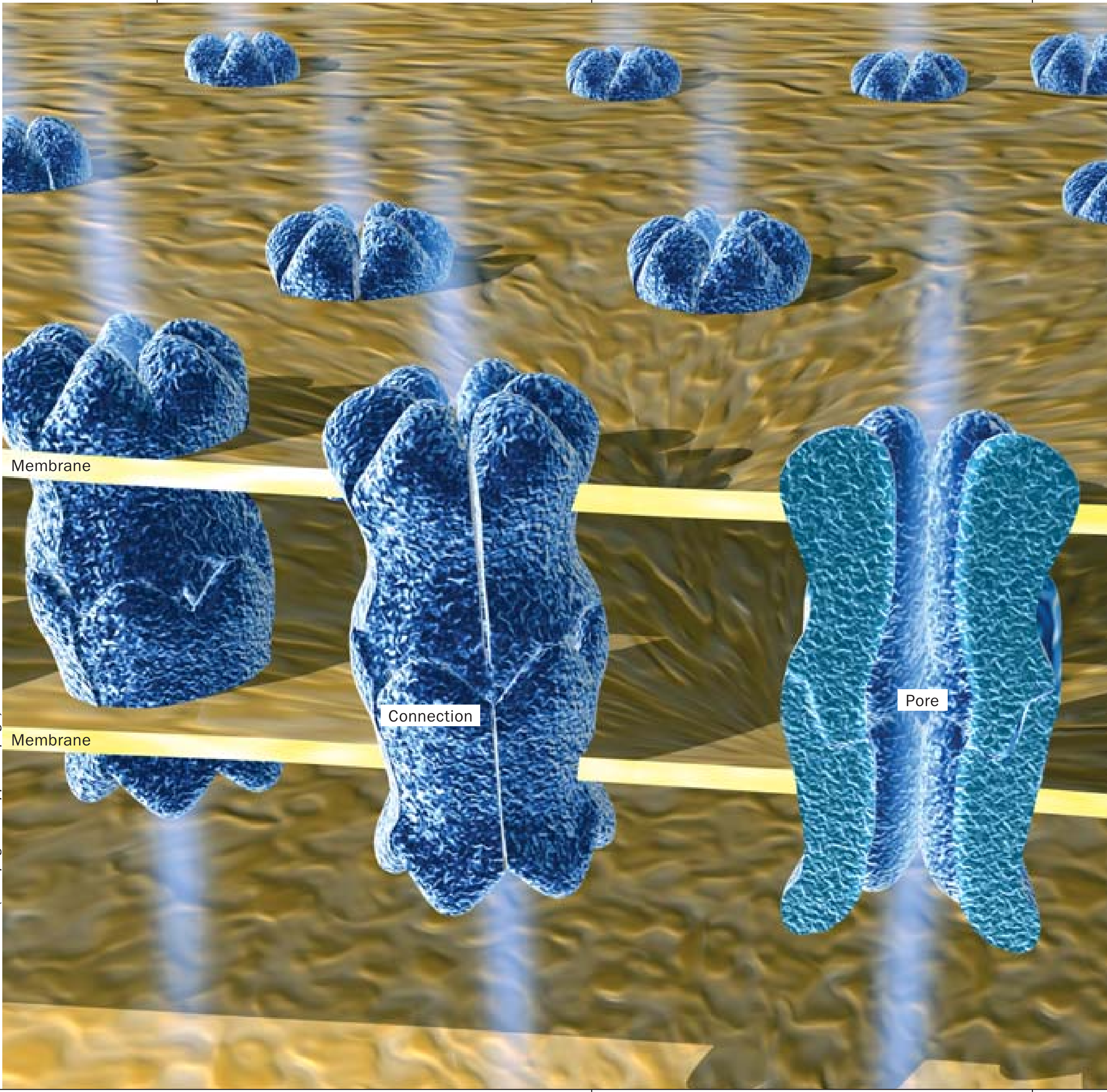
By Rolf Dermietzel

CORBIS

Too hot! As our fingertips graze the hot stove, their thermal receptors sound an alarm. The message races at 300 kilometers an hour through the nervous system to the brain, where it gets immediate attention. The muscles receive an order to pull those fingers away from the surface.

Such messages—encoded as electrical impulses—constantly stream through our nervous system. They not only prevent us from burning our fingers on the hot stove but also enable our very survival.

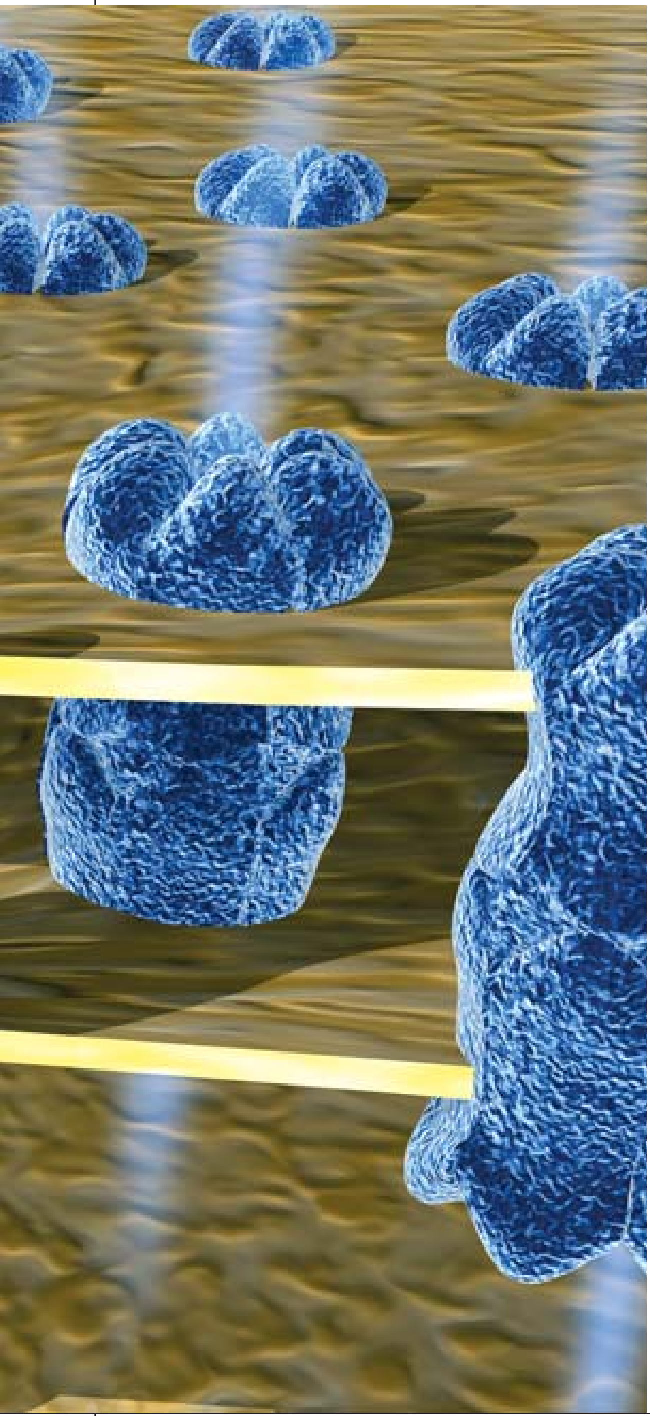
A century ago some neurophysiologists believed that these impulses traveled through unbroken paths, in a system akin to the electric cables or water pipes in a home. Others argued that every neuron was an island unto itself. Today we know that both camps are partly right [see "Beyond the Neuron Doctrine," by R. Douglas Fields; SCIENTIFIC AMERICAN MIND, June/July]. Most neurons communicate via messenger



SIGANIM Gehirn & Geist (this page and opposite page)

(Research on electrical synapses remained almost as exotic as blowfish preparation for a long time.)

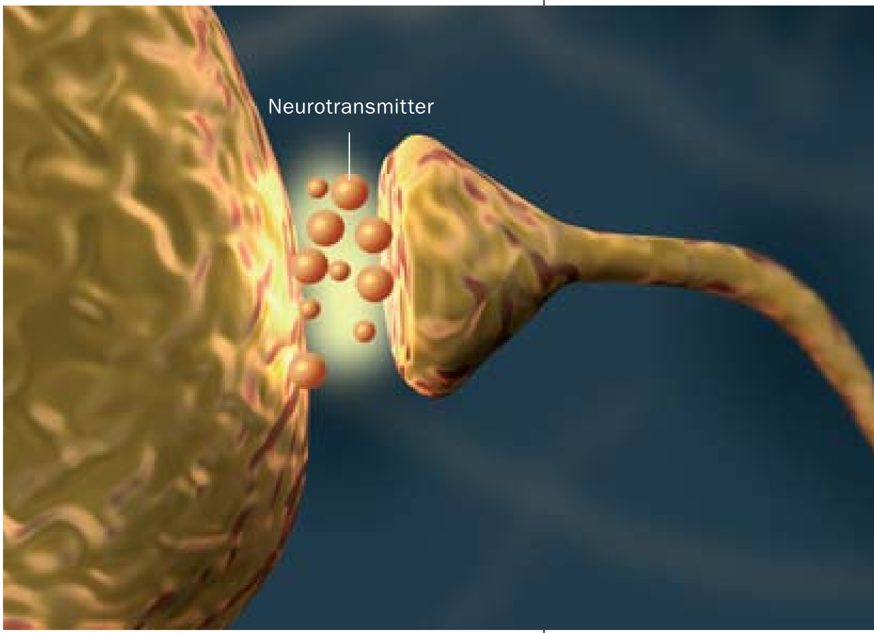
compounds called neurotransmitters that travel across gaps, or chemical synapses, between the cells. Some neurons, however, also have physically continuous, pipelike connections to other cells, which scientists call electrical synapses.



Electric Speed

Although chemical synapses have gotten most of the attention, evidence existed for the electric alternative as long ago as the middle of the 20th century. In 1957 neurophysiologists Edwin Furshpan and David Potter, now both professors emeritus at Harvard Medical School, first reported finding direct electrical conduction of signals in the giant motor neurons of crayfish. That year Michael V. L. Bennett, now at the Albert Einstein College of Medicine, described the same phenomenon in his work with the toxin produced by the blowfish, the (sometimes deadly) delicacy *fugu* beloved in Japanese cuisine. Further research on electrical synapses remained almost as exotic as blowfish preparation for a long time. Only in the past few years has science unraveled the cellular workings at the molecular level.

The advantage of electrical synapses over their chemical counterparts is obvious: by omitting neurotransmitter middlemen, electrical synapses conduct impulses from one neuron to the next at far higher speeds. Chemical synapses secrete neurotransmitters, which must cross the



An electrical synapse consists of many channels (*blue, left panels*) that make the cell membrane permeable for ions to deliver messages. Each channel has 12 membrane proteins called connexins that convey signals directly. In a chemical synapse (*above*), neurotransmitter chemicals carry signals between cells.

(The Author)

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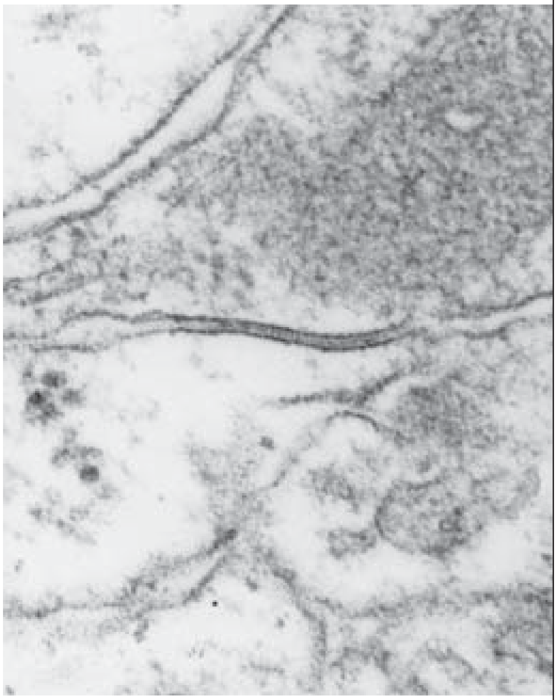
Electrical synapses appear to play a role in the synchronous firing of large sets of neurons.



The electron microscope reveals the synaptic cleft, or gap, of a chemical synapse (*left*). In the electrical type (*right*), proteins bridge the gap.

ELISABETH PETRASCH-PARWEZ *Ruhr University Bochum*

synaptic gap to deliver their message. The entire process takes about half a millisecond. That may seem fast, but for many physiological processes—such as the flight reflex of the blowfish, during which it instantaneously flips its tail to escape predators—it would be too slow for survival. In such cases, electrical synapses are at work, delivering their signals almost without delay.

Synapse Secrets

How do they work? Linked membrane proteins form a conduit between neurons. In the middle there is a pore through which positively charged particles, or ions, can flow from one cell into the next. There, by means of a kind of controlled short circuit, they cause an impulse called an action potential, which can then be sent onward by the next cell.

Electrical synapses appear to play a role in the synchronous firing of large sets of neurons, as was discovered independently in 2001 by Barry Connors of Brown University and Hannah Monyer's lab at the University of Heidelberg in Germany. The researchers found that in mice lacking a gene for creating electrical synapses, nerve cells could not fire rhythmically in the 30- to 60-hertz range. Furthermore, electrical synapses were especially prominent in certain interneurons (which communicate only with other neurons) in the cerebral cortex and hippocampus. These cells, in turn, inhibit, or help to regulate, higher-level nerve networks that process sensory perception and control muscle movements. Apparently, the interneurons that are connected by electrical synapses filter the incoming flood of data by transforming the stimuli into rhythmic discharges, and by then propagating these rhythms over large distances. The electrical synapses thus generate the rapid spread of rhythmic activity, activating different brain regions almost simultaneously.

The electrical synapses are known as gap junctions because of their appearance under an electron microscope. These fast contacts are concentrated in certain regions, where the precise synchronization of large groups of cells is vital. Gap junctions deliver, for instance, the electric stimuli that enable the coordinated contraction of the heart. They also are found in the olfactory bulb, in the center of the brain stem, in the retina and among the pyramidal cells in the hippocampus, where they are involved in a special type of memory storage.

Electrical synapses' fast communication is important during embryonic development. In the developing rodent brain, gap junctions couple together undifferentiated stem cells, the precursors of more mature neurons. These synapses are not yet capable of synchronizing electrical activity, because the precursor cells cannot fire. Instead they are involved in controlling cell division, as Arnold Kriegstein, now at the University of California, San Francisco, showed in 2004. When the researchers inhibited the gap-junction coupling of the embryonic cells, cell division went completely out of control. The regulated increase in the number of precursor cells is crucial to brain maturation, because the cells must move from the fluid-filled inner zones of the brain into the surrounding tissue in groups that later develop into individual brain regions. When the neuronal precursor cells are uncoupled, the consequences are fatal.

After birth, electrical synapses continue to play a key role in brain development. In rats these cell connections exist between virtually all neurons during the first two weeks after birth. As these cell connections drop in number, chemical synapses increase, as Karl Kandler, now at the University of Pittsburgh, and the late Lawrence C. Katz of Duke University described in 1998. Their spontaneous development may help to sculpt immature circuits. As neuronal circuits mature and create their own chemical synapses to process sensory experiences, most of the gap junctions gradually disappear.

The postnatal boom for electrical synapses reflects the fact that gap junctions represent an ancient principle of cell communication. Even simple multicellular organisms, such as sea squirts and sponges, have gap junctions. It is striking that electrical synapses appear very early on in the developing nervous systems of mammals, whereas their chemical counterparts do not show up until after birth. Apparently, the electrical connections are meant to keep communication going between neurons until the final, chemical connections are established. As the electrical synapses pass the baton to their chemical siblings, they clear the way for the construction of the complex brain.

Gaps Gone Wrong

Flaws in gap junctions appear to play a role in many neurological disorders. For example, in epileptic seizures huge populations of neurons spanning several brain regions fire synchronously [see "Controlling Epilepsy," by Christian Hoppe; Scientific American Mind, June/July]. All the evidence speaks for the involvement of electrical synapses: they are found in a network of neurons that is normally responsible for inhibiting the overlying nervous system in which the attack takes place; scientists have observed epilepsylike discharges by groups of neurons that are electrically coupled in isolated areas of the brain; and in 2004 researchers led by Christophe Mas of the University of Geneva discovered that in an inherited form of epilepsy, the gene that codes for the main protein in electrical synapses is altered. Given the recent findings, it may be possible in the future to treat certain forms of epilepsy with drugs that reduce the excitability of electrical synapses.

Gap junctions may also be involved in the aftermath of strokes. Neurologists have long wondered why the size of the damaged area continues to increase for many hours after the stroke event, far beyond the region originally affected. The reduction of this penumbra, which surrounds the original site of destroyed tissue like a halo, would constitute an enormous advance in the treatment of stroke.

The key to solving penumbra damage most likely lies among the astrocytes, non-neuronal cells named for their starlike shape. Like nurses, these cells make sure the neurons around them receive a balanced diet of ions, neurotransmitters and growth factors. The astrocytes are themselves coupled to each other through countless thousands of gap junctions, making an intensive exchange of molecules possible. Thus, this network could also distribute the harmful metabolic products resulting from the massive death of brain tissue, thereby damaging cells not killed directly by the stroke.

Whether research into these direct nerve cell contacts will provide promising new therapies remains to be seen. What is certain is that the electrical synapses have lost their wallflower status and are now taking their rightful place as fascinating and important objects of research. M

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When the Nose Doesn't Know

LOSS OF SMELL CAN BE DISTRESSING AND IS ASSOCIATED WITH DISORDERS SUCH AS DEPRESSION. SMELL TRAINING MAY HELP RECOVER THE SENSE BY ELEONORE VON BOTHMER

Magdalena Fluegge is devoted to her exercise routine, and she has been training hard for months now. Every morning and afternoon, without fail, she hefts four small brown glass vessels. They contain gauze strips saturated with different fragrances. She opens each flask in turn and inhales deeply. She hopes for a scent—any scent—to register in her brain.

Fluegge, who lost nearly all her ability to smell after striking the back of her head in a bicycle accident, is a volunteer in a study at

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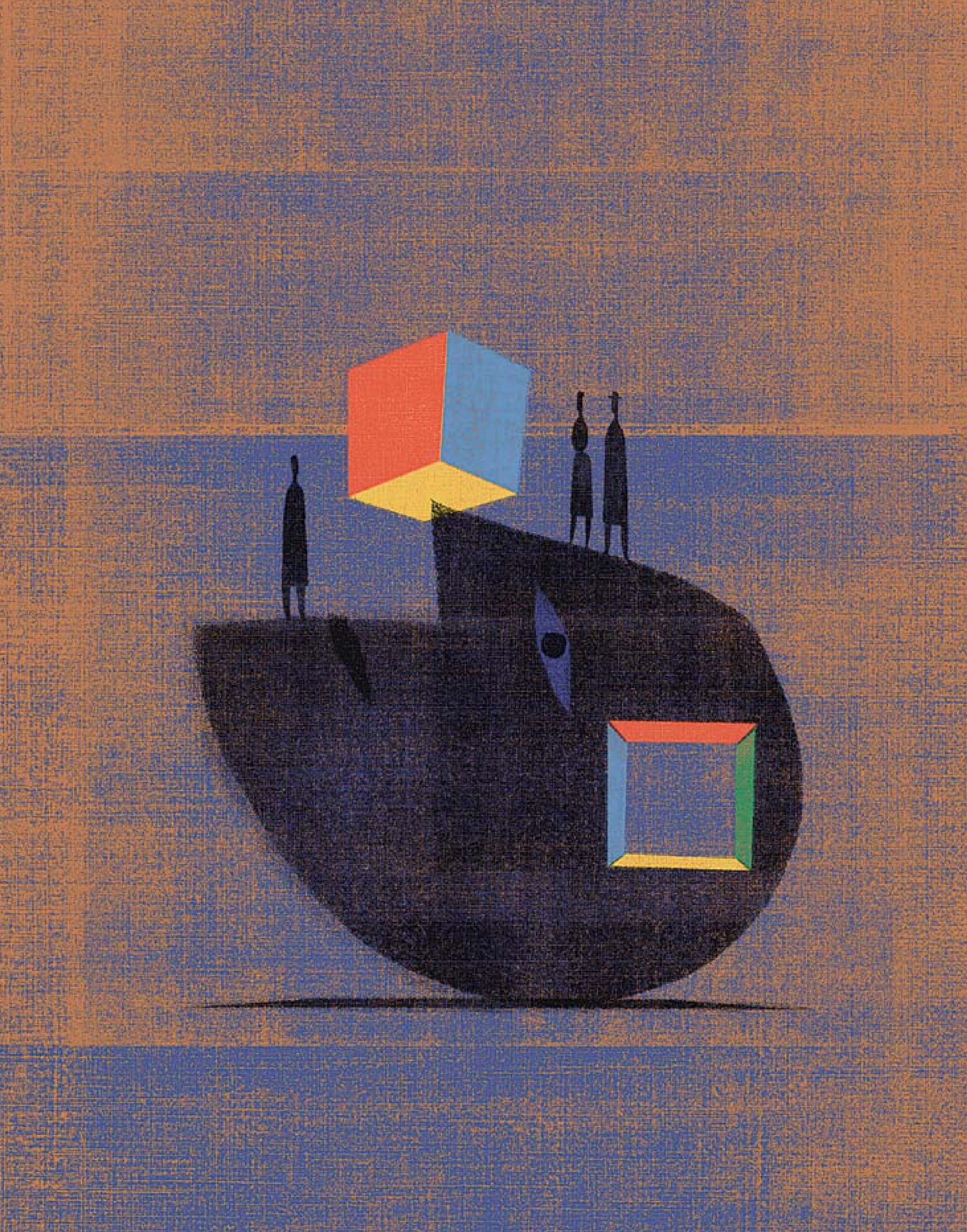

Humans can perceive some 10,000 scents, and specific odors can elicit memories.

Every breath draws scent molecules to our smell detectors.

the Ear, Nose and Throat Clinic at the University of Dresden Medical School in Germany. The goal is to see whether people with smell disorders can regain their abilities through training, similar to the way perfumers and sommeliers can learn to discern expertly among samples.

"Smell is perhaps our most evocative sense," biochemist and molecular biophysicist Richard Axel of Columbia University has written; his work in uncovering the molecular mechanisms of smell garnered him the 2004 Nobel Prize in Physiology or Medicine. Humans can perceive some 10,000 scents, and specific odors can elicit memories or behaviors. In his *Remembrance of Things Past,* Marcel Proust describes how the fragrance of a madeleine cake dipped in linden tea suddenly sent him back to his childhood. When an intense memory is evoked by a sudden whiff of a fragrance, we call the phenomenon the madeleine effect. Smells evoke memories, without which keys to our own pasts would be missing. The sweet presence in the air of an apple pie baking may instantly awaken fond childhood recollections of cooking with Mom, for instance.

Smell also gives different foods their characteristic flavors, as anyone who has suffered from a bad head cold can attest. Without smell, food loses much of its appeal; taste buds detect only sweet, sour, salty, bitter or umani (savory). The sense confers important survival benefits, too. A pungent stink alerts us to the hazard of a nearby skunk; an unpleasant tang warns us away from spoiled milk.

Smell is, from an evolutionary point of view, one of the oldest senses, and it is more strongly associated with emotions—which evolved early—and less with reasoning.

Without smell, some of the most intimate of all experiences would lose their foundation: a mother not being able to smell her child or a husband the body of his wife. A research team led by psychologist Bettina M. Pause, now at Heine University in Dusseldorf, Germany, demonstrated in 2001 that depressed individuals often have a poorer olfactory sense than healthy people—although it is not yet clear whether this symptom is a cause or an effect of mental distress. As researchers pursue a better understanding of how smell works, they may find clues to restoring the sense.

Scent to the Brain

Every breath draws scent molecules into our nostrils. The mucous membranes inside the nose contain olfactory cells with fine hairs, or cilia, that absorb the tiny airborne particles from gasoline, a rose or manure. They send signals on to the olfactory nerve, a fiber bundle that ends at the olfactory bulb in the brain. From there, scent information is passed to the olfactory center, which is connected to the limbic system, the emotional seat of the brain, where incoming smells are identified and classified.

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Many factors can lead to the loss of smell. About 5 percent of all people cannot smell at all, a condition called anosmia; more are like Fluegge, who has hyposmia, a partial inability. In rare cases, the defect is hereditary, and the victims—overwhelmingly female—are anosmic from birth. Smell also declines with advancing years; 25 percent of people older than 60 have to do without it. Sometimes a nasty virus or cold damages receptor cells. "About 8 percent of all cases of smell disorders are caused by accidents," adds Thomas Hummel, who leads the clinic's team. "A classic is falling and hitting the back of the head: during rebound, the olfactory lobe, which is in the front of the brain, behind the eyebrows, is jolted forward. There it collides with the bones of the skull. The olfactory nerve is often torn."

"In fact, the human sense of smell is based on two nerves," Hummel continues. "The olfactorius is a pure odor detector, whereas the trigeminal nerve has more to do with feelings and sensing pain, and it comes into play with pungent odors such as ammonia or onions. This second nerve remains, for many anosmics, intact." He picks up an ivory-colored plastic skull from the shelf, opens it, and traces the path of the nerve with his finger. "The bulbus olfactorius, the olfactory bulb, leads directly to the brain. This point is very vulnerable. But for most accident victims with smell disorders, only the olfactory nerve is torn or crushed—and thus the link between the nasal mucosa to the olfactory bulb is cut."

Fluegge lost her sense of smell in a bicycle accident. When she landed on the back of her head, she suffered a concussion. Later, she went for a walk in the woods. "I had always enjoyed the fragrances there," she recalls. "I realized suddenly: I don't smell anything. I would pick up moss and grass and stick them under my nose, but nothing happened. Nothing." Her fears were soon confirmed: "I would deliberately walk behind people smoking and would think, 'Now I am going to smell something.' But I wouldn't. Nothing."

Loss of smell may also be a symptom of another ailment. At the onset of some neurodegenerative diseases, such as Alzheimer's and Parkinson's, people often lose the ability to smell. "To begin with, we try to find the underlying disorder," Hummel explains. "Because the rate of misdiagnosis for Parkinson's is about 20 percent, this is an important indicator."

To Smell Again

"For most types of smell disorders, there is no proven method of treatment," Hummel says. But "occasionally the sense of smell suddenly comes back to life—with or without treatment." For between 10 and 20 percent of patients, the sense of smell returns naturally.

The clinic's work on smell-training therapy springs from a key distinction of olfaction: our nose possesses a special ability not shared by eyes or ears. Its sensory cells regenerate to replace themselves every four to six weeks. Taking a cue from the educated noses of professional sniffers, the doctors in Dresden hope that continual practice by patients will animate disabled sensory cells to reproduce, making them more sensitive and improving the processing of smell data by their brains. The cost and complexity of such therapy are minimal. In a small, brightly lit lab in the basement of the old building that houses the Dresden clinic stands an unassuming army of brown glass jars in ranks atop a cart—pipettes,

Strong odors warn us away.

GK HART AND VIKKI HART *Getty Images*

(The Author)

ELEONORE VON BOTHMER is a psychologist and science writer who is based in Frankfurt, Germany.

Occasionally the sense of smell suddenly comes back to life—with or without treatment.

Smell can evoke memories—perhaps of baking with Mom.

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an atomizer and the racks holding the three rods of a test called the Sniffin' Stick.

Every six weeks Hummel and his colleagues test Fluegge to see whether her nose has learned anything. Hours into the process, the blindfolded woman continues to hold her nose up in the air out of habit, although her shoulders have begun to sag from fatigue. She whiffs a spectrum of everyday odors in turn, such as lemons, flowers and spices. Some Sniffin' Sticks have such an intense stench—dried fish, for example—that clouds of scent overwhelm the room, causing even Fluegge to grimace. Suddenly, she jumps. Turpentine or coffee? "That may be coffee," she whispers. Right. She also recognizes cloves, and her self-confidence increases.

Wires attached to Fluegge's head record her brain activity in response to the samples. Fed a constant stream of data, the computer calculates the results and then spits out the final tallies. Fluegge pulls the blindfold off, and, dazed by the light, she blinks. "Overall the results are a little better than last time," the tester announces.

But the smell marathon is not over yet. Johannes Frasnelli has prepared the next trial. Four squeezable plastic bottles stand ready. "First we

Smell helps to anchor our emotional experiences.

STUART WESTMORLAND *Corbis*

worked on the olfactory nerve, now on the trigeminal, the sensory nerve," the young doctor explains. "We will do that with the squeezer," he says as he arranges two of the milky-white plastic bottles in a metal apparatus about four inches tall. "One of them contains eucalyptus, the other nothing," he tells her.

Fluegge gets ready, her eyes covered again. Then Frasnelli inserts two of the little red nozzles on the bottle tops into her nostrils. He presses the squeezer together. "Raise your hand on the side on which you smell the eucalyptus," the doctor instructs. Fluegge sits still, waits, then raises her left arm. The routine continues: inserting the nozzles, squeezing, waiting for the hand signal, switching the bottles—each switch is marked by the same hollow sound of the soft plastic sliding into place. Again. And again. Forty times. The rhythm is precisely calculated—a series of eternities, each lasting 40 seconds. When the patient finally removes her blindfold, she learns that this time she got almost everything right. Her trigeminal nerve is relatively undamaged, so that she can still sense penetrating odors.

Now comes the last test of the day. Inside a lab packed full of equipment, an olfactometer awaits. The instrument is a colossus covered with dials, wires and buttons; it fills the room. Through a long tube, various fragrances are blown into the nose. The brain activity each scent arouses will be measured with electrodes that detect so-called evoked potentials.

Wires are quickly attached, and Fluegge's head appears as if it is festooned with spaghetti. She is told not to blink. Gas begins to blow through the tube. Little x's on the screen show the strength of the stream of gas entering her nose. It is tiresome work, but Fluegge is resolute. "Being blind is definitely worse," she remarks, "but smells were always important for me. It is only since they no longer exist for me that I have realized just *how* important. I have lost a warning system. Once my son ran up to me and screamed: 'Can't you smell that?' The skillet on the stove was red-hot."

Even if she does not profit further from the smell-training program herself, Fluegge views the chore optimistically. She hopes that the knowledge gained from her participation will alleviate the condition of fellow sufferers in the future. M

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Detecting Autism Early

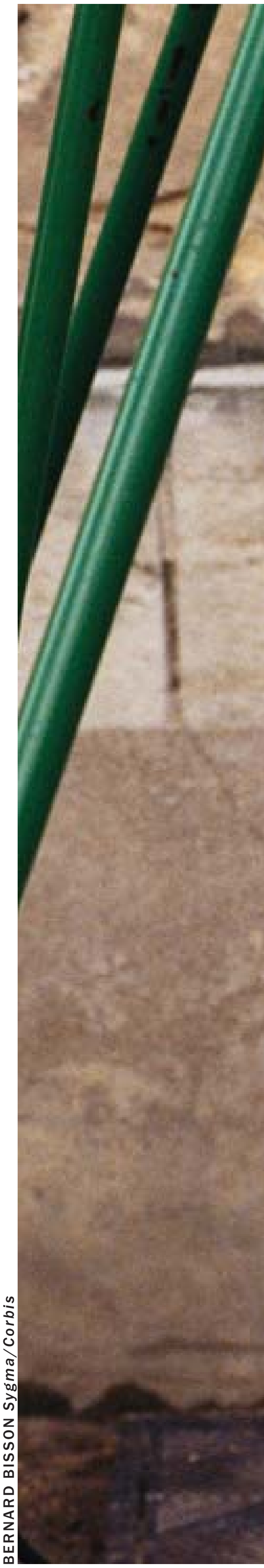
New techniques could diagnose autism in babies, enabling more effective treatment while the brain is most malleable

By Ulrich Kraft

Anyone who has spent even a little time with an autistic boy or girl soon becomes familiar with the behaviors that set these children apart: lack of eye contact, trouble verbalizing, overreacting or underreacting to activities around them, difficulty in expressing their feelings and in understanding the emotions of others. But how do parents and doctors know if a baby, who is too immature to be gauged on any of these traits, has autism? Early diagnosis has proved difficult.

Inability to detect autism until a child is two or three years old is a terrific disadvantage. It "eliminates a valuable window of treatment opportunity, when the brain is undergoing tremendous development," says David G. Amaral, professor of neurobiology and psychiatry at the University of California, Davis.

Amaral and researchers at other institutions, however, are closing in on techniques that could detect autism in babies as young as six months and perhaps even at birth. The results of these new tests—some controversial—are expanding the understanding of autism and raising hopes for much earlier, specialized care that could improve a toddler's chances for a more normal life as a child, teenager and adult.



BERNARD BISSON *Sygma/Corbis*

> Tests showed that autistic children had different levels of **immune cells** and proteins in their blood.

Gwendoline, age 6, is comforted by her mother. Some children may not be doomed at birth; something in their infant environment might trigger a genetic predisposition.

BERNARD BISSON *Sygma/Corbis*

A Simple Blood Test?

Autism affects a wide variety of developmental traits. Some young autistic children speak; others do not. Some possess almost average intellectual abilities; others are severely limited. As they grow older, certain autistic individuals display incredible talents in very specific domains. Known as savants, they can memorize an entire book in hours or solve complex math problems faster than people using a calculator. The 1988 movie *Rain Man* dramatized these abilities in a character named Raymond Babbitt, played by Dustin Hoffman, who won an Oscar for the role. Babbitt was based on a real savant named Kim Peek, who continues to astonish today [see "Inside the Mind of a Savant," by Darold A. Treffert and Daniel D. Christensen; Scientific American Mind, June/July].

It is no wonder, then, that determining whether a young child is autistic is fraught with uncertainty. Diagnosis typically involves rating a child's behaviors against a set of standards. The exercise usually is not conclusive until at least the child's second birthday. That is why scientists are seeking an earlier and more accurate test, and they are getting closer. At the International Meeting for Autism Research in Boston in May 2005, Amaral presented the initial results of a landmark study. His team compared blood samples from 70 autistic children ages four to six with samples from 35 randomly selected subjects in the same age group. The autistic children had a higher proportion of two basic immune system cells known as B cells and T cells. Significant differences also became apparent in more than 100 proteins and small molecules commonly found in the bloodstream.

After further analysis, the team decided that the pilot study results were strong enough to launch a full-scale investigation. In March, Amaral announced that U.C. Davis's Medical Investigation of Neurodevelopmental Disorders Institute, which he heads, was starting the Autism Phenome Project. It will enroll 900 children with autism plus 450 more who have developmental delays and 450 who are developing normally. Researchers will analyze the children's blood proteins, immune systems, brain structures and functions, genetics and environmental exposures. The participants will be two to four years old at the outset and will be followed for several years. Amaral thinks it is probable that telltale genetic markers will be found. But it will take several years before the project is finished and analyzed and longer still before a routine test could be administered at a doctor's office.

If the blood profiles prove to be reliable, the screening could occur just after a baby is born. But the validity of detection that early in life requires more scrutiny. Amaral says there is a growing view among experts that not all individuals who have autism are "doomed at birth," as has been commonly believed. "It may be that some children have a vulnerability, such as a genetic abnormality," he says, "and that something they encounter after being born, perhaps in their environment, triggers the disorder."

Environment is suspected in part because the incidence of autism is fairly high in American children. The disorder affects one in every 500 to one in every 166 children, according to the U.S. Centers for Disease Control and Prevention. The unexplained preponderance has frustrated scientists trying to find answers. Furthermore, tremendous variation exists among symptoms, "which leads us to believe that autism is a group of disorders rather than a single disorder—several autisms versus one," Amaral says. The blood work possibly could define distinct subtypes. Behavioral experts are reaching the same conclusion, many preferring the term "autism spectrum disorder" rather than simply "autism."

Earlier Treatment Is Key

An early diagnosis is so important because it would allow treatment to begin sooner, while the brain is still significantly strengthening and pruning neural networks. A paradigm shift is taking place on this issue, too. For a long time, scientists believed that functional deficits in certain brain regions caused autism—complications in brain structure that no change in wiring among neural networks would fix. Now they think symptoms arise because of communications problems between brain regions—problems that rewiring could solve if babies received specific therapy.

"The neuronal networks apparently do not coordinate very well," explains Fritz Poustka, director of child and adolescent psychiatry at Goethe University in Frankfurt, Germany. Poustka says regions that get too little input from other parts of the brain do not develop well. This effect is well known among children who were neglected when they were young, some isolated from almost all human contact. A child who develops this way shares some similar consequences, such as poor use of language and difficulty in making social connections. "A quick diagnosis of autism would enable us to stimulate the networks very early in life by deliberately providing the right inputs," Poustka says. He cannot say if such interventions would "cure" the disorder, but he believes that intensive behavioral training could make the symptoms milder.

Although Poustka doubts that markers in the blood would permit early diagnosis, he favors attempts to try to define telltale traits as young as possible to maximize the success of treatment. In speech development, for example, the best results are achieved when deliberate exercises are instituted before the child's second birthday. By the time a boy or girl is three or four, deficits can still be reduced, but fundamental changes are no longer possible, because the critical period during which speech develops has passed by.

Behaviors Untangled

Whether or not Amaral's project leads to common blood tests, it could prove beneficial to behavioral approaches as well because it includes developmentally delayed children. The standardized checklists that doctors now use for diagnosis, such as the "autism diagnostic observation schedule," are adequate only for children who are at least one and a half to two and a half years old. And then, usually only for the so-called high functionals—

Certain situations are difficult for autistic children to understand. If they could be diagnosed as babies, earlier behavioral training could make symptoms milder.

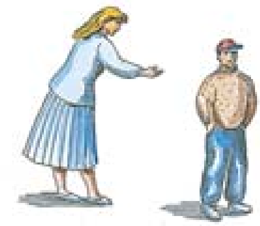
BERNARD BISSON *Sygma/Corbis*

(The Author)

ULRICH KRAFT is a contributor to *Gehirn & Geist*. He wrote about the brain's own marijuanalike chemicals in the August/September issue of *Scientific American Mind*.

Common Behaviors

The traits most characteristic of autistic people are aloneness, an insistence on sameness and a liking for elaborate routines. At the same time, some autistic individuals can perform complicated tasks, provided that the activity does not require them to judge what some other person might be thinking. These traits lead to characteristic forms of behavior, a number of which are portrayed here.
—Uta Frith, University College London



Displays indifference

Is one-sided in interactions

Indicates needs by using an adult's hand

Talks incessantly about one topic

Joins in only if an adult assists

Parrots words

Behaves in unusual ways

Does not play well with other children

Laughs and giggles inappropriately

Handles or spins objects

Does not make eye contact

Does not pretend in playing

Prefers sameness

Yet performs certain tasks well if they do not involve social understanding

RODICA PRATO

autistic children with IQs over 80. The tests are inconclusive for many of the other suspected individuals because children who are delayed in their intellectual development often score similarly to children who truly have autism. It is difficult to determine whether cognitive problems are being misdiagnosed as symptoms of autism, Poustka says. Delay, or a completely different disorder, can prompt what appear to be autismlike patterns.

A Canadian research team is trying to clarify this overlap. Led by Lonnie Zwaigenbaum, a developmental pediatrician at McMaster University in Ontario, they devised a 16-point observational checklist called the Autism Observation Scale for Infants and used it to evaluate 65 one-year-old children, all of whom had older siblings with autism and therefore had an above-average chance of developing the disorder themselves. They also assessed another 23 babies with no familial ties to or signs of autism.

Jay, 23, walks to Bingo night, the one social activity he does on his own. Offering autistic toddlers a more fruitful childhood raises their chances for more satisfying years as adults.

KAT WADE San Francisco Chronicle/Corbis

(Children diagnosed at age two had shown seven or more **telltale behaviors** when they were only one.)

Zwaigenbaum's group reappraised the children when they were two, this time using traditional tests. They found that almost all the children who were diagnosed as autistic at age two had seven or more distinguishing traits when they were only one. "The predictive power of these markers is remarkable," Zwaigenbaum says.

Even among children just six months old, certain behavioral patterns forecast the onset of the disorder, notably a passive temperament and low physical activity levels. By their first birthdays, the children who later turned out to be autistic were easily irritated, had problems with visual tracking, tended to focus on a very few objects, failed to look around for a speaker who said their name, and barely interacted with others. They also tended to have certain obsessive motions, such as stroking surfaces, yet made very few gestures toward other people. And they understood less spoken language than their age-mates who were later identified as nonautistic.

As Amaral acknowledged about his first blood-profile exploration, Zwaigenbaum notes that further studies must include children who are at risk for other developmental disorders to help distinguish which symptoms are specific to autism. He is also open to the possibility of environmental influences in triggering or at least exacerbating autism. He says it is hard to know if the traits his group identified are early manifestations of the disorder or if they contribute to a pattern of development that may lead to autism.

Either way, his investigation, Amaral's and those of others are all improving our understanding of when autism starts, providing hope for earlier diagnosis and more effective treatment. The goal, of course, is to offer toddlers a greater chance at a more fruitful childhood, which in turn raises their chances for more satisfying years as teenagers and adults. The many challenges that autistic individuals face as they mature—learning, communicating with others, making and keeping friends, building life skills, securing a job, finding love—will be less daunting if they can get off to an earlier, better start. M

(Further Reading)

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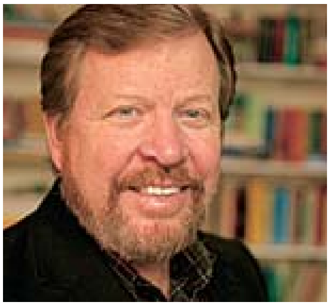
- **Autistic Brains Out of Synch?** Ingrid Wickelgren in *Science,* Vol. 308, pages 1856–1858; June 24, 2005.

Don't Count on It

TOMEK SIKORA *Getty Images*

A small Amazon tribe, the Pirahã, have no number system. Is the reason neurological—they cannot count—or psychosocial—they just do not want to?



Daniel L. Everett, professor of phonetics and phonology at the University of Manchester in England, spent seven years with the Pirahã (pronounced pee-ra-HA), a hunter-gatherer tribe of 200 who live in groups of 10 or 20 along the Maici River in the Lowland Amazon area of Brazil. These people call themselves Hi'aiti'ihi': those who stand straight. Everett studied their culture and language—and stumbled on an oddity: the Pirahã have no numbers or clear words for quantities, have no differentiated words for familial relationships, and only a few to describe time. They do not read or write, do not talk about abstract subjects, do not use complex sentences and do not learn Portuguese, even though they are in constant contact with the outside world.

Everett's colleague Peter Gordon, professor of speech and language pathology at Columbia University, also carried out speech tests in the Pirahã villages. He found the members had a quantification system with terms for "one," "two" and "many." He has argued that the Pirahã have only a few numerical words because they cannot count higher. Everett takes a very different view, which he outlined during an interview with Annette Lessmoellmann.

Annette Lessmoellmann: How does a Pirahã mother count her children?
Daniel Everett: She would never say, "I have five children." But she does not need to do so, either. After all, she knows her offspring by name and face. If she wants to take them somewhere, she always looks them over first. She does not have to count to do so. If one mother has eight children, and another has just one, then they would say something like this: "I have a lot of children," and "I have a small quantity."

AL: But aren't numbers awfully practical?
DE: The Pirahã don't need them. When everyone jumps into the canoes, they don't say: "We still have space for three people here." Instead they say something when the canoe is so full it might sink. When they make soup, they say: "You fish in" instead of declaring the quantity in advance, such as "You two fish in." They simply yell, "Stop," when it's enough.

AL: Does that mean the Pirahã do not even have the words "one" and "two," as your colleague Peter Gordon states?
DE: Yes, that's right. I discovered that the word that apparently meant "one" really meant "small." They would use it for a baby, for example, not because there was one baby but because it was small. The word I had long believed to mean "two" they used for bigger kids, too. These concepts reflect relative sizes. They are not precise, because their meaning is clear from the context. And

PAUL CLIFF

(The Author)

ANNETTE LESSMOELLMANN is a linguist who works on the editorial staff of *Gehirn & Geist*.

How many? A Pirahã mother might speak of having a small or large family (*left* and *right*)—but not a precise number. The tribe lives in the Amazon basin (*map*).

the word that I thought might mean "many" turned out to be an expression for "collecting" or "grouping" and thus did not mean a quantity. The Pirahã do not have precise expressions like "10."

AL: How did the discrepancies between your findings and Gordon's come about?

DE: In fact, we agree. The Pirahã have no counting words and don't count. But Gordon should have chosen other research methods. He worked with [asking villagers to count] AA batteries and plastic sticks during his tests. Those are not Pirahã objects, and for such a self-sufficient culture, that was fatal. The big difference between Gordon and me, though, is the argument over why the Pirahã have no counting words and cannot count. He says they are cognitively incapable of counting.

AL: Many researchers would have drawn that conclusion. It is after all a classical belief in linguistics that common cognitive tasks are closely connected to language.

DE: Of course. People such as linguist Noam Chomsky of the Massachusetts Institute of Technology or psychologist Steven Pinker of Harvard University believe in an inborn language ability that grows out of our innate intelligence.

In this sense, Gordon's findings point in the opposite direction, namely, toward the hypothesis enunciated by anthropologist Benjamin Lee Whorf, in which one's mother tongue influences thinking. In this case, it means that the Pirahã don't know any counting words; therefore, they cannot think in numbers. All these approaches have one thing in common, in that they are based on a very close connection between language and cognition. These hypotheses completely ignore, however, what roles other influences such as culture might play.

AL: Could you explain such an influence with an example?

DE: When we ask Pirahã to string beads—and this is a very typical activity for them—the adults are not able to count the beads from one to nine. But we did determine that children learned the numbers.

DANIEL L. EVERETT (*top left and top right*); EMDE-GRAFIK/GEHIRN & GEIST (*bottom*)

AL: This means that they are cognitively capable?
DE: Exactly. They are also interested in numbers. Once the adults asked me to give them counting lessons. They wanted to understand what this silly money that the Brazilian traders were constantly offering them was all about. For two months we tried to teach them the most basic rudiments, without success. They had not learned a single number, not to mention the fact that they could not write them. Perhaps they could repeat the numbers, but they never used them in daily life.

AL: But doesn't that in fact confirm that the Pirahã are cognitively incapable of counting?
DE: No. Many languages that are historically comparable to the Pirahã's also lacked counting words for a long time. For example, many Australian languages borrowed counting words from other languages. The people's culture changed and their need for counting words grew, so they borrowed some. That would not have been possible if the nonexistence of counting concepts meant that these people were not, in principle, able to count.

I believe, to the contrary, that the Pirahã do not want to count! It is exactly the same with learning Brazilian Portuguese. The Pirahã have a lot of contact with the outside world, but they refuse to learn the national language. A girl had to spend a long time being treated in a hospital in the city. When she returned, I noticed that she could now speak Portuguese well. But after a little time back in the village, she did not use it at all anymore. The Pirahã have made it a matter of principle not to learn foreign languages. It is true they are constantly asking, "What is this called, what is that, in Portuguese?" But it is mostly a game. They could have learned these words long since, but they don't want to. It is the same with counting. I observed that a boy, about 11 years old, who had learned to count, was shunned by the others.

AL: So you are saying the lack of counting words among the Pirahã should be considered in connection with the other special characteristics of their language?
DE: Precisely. When I started out working among the Pirahã, I searched in vain to find stories that had been passed down. They don't have any. And they never begin a story with "once upon a time" and do not talk about the adventures of an event. I asked them: "What was it like a long time ago, before there were any Pirahã?" They did not understand me; there have always been Pirahã.

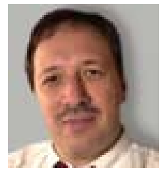
AL: So the Pirahã only talk about concrete things?
DE: In a certain sense, yes. I call this the "principle of direct experience." It is not true that they only talk about things that are going on around them right now. A conversation with someone who had recently died belongs to direct experience: the person is certainly not there anymore, but one remembers the conversation. They also certainly know tomorrow and yesterday. But they don't have words for them. There is only one word, meaning "the other day." Whether it is in the past or the future is determined by context. If I want to tell them when I will be leaving, I show them, at the riverbank, how high the water will be then. They understand immediately.

(Many languages that are historically comparable to the Pirahã's also lacked counting words for a long time.)

AL: Your results show that cultural variety can be reflected not just in words but also in sentence construction. You maintain that Pirahã permits no embedding, meaning no subordinate clauses. But that is a hallmark of human language.
DE: Linguistic complexity depends on which developmental phase a culture finds itself in. Languages develop, and with this their complexity, meaning the degree of nesting. Apparently the Pirahã don't possess this from birth. Language, thus, has less to do directly with our biologically determined cognitive abilities than Noam Chomsky, Steven Pinker and others would like to have it. **M**

(Further Reading)

- **Numerical Cognition Without Words: Evidence from Amazonia.** Peter Gordon in *Science,* Vol. 306, pages 496–499; October 15, 2004.
- **Cultural Constraints on Grammar and Cognition in Pirahã: Another Look at the Design Features of Human Language.** Daniel L. Everett in *Current Anthropology,* Vol. 46, No. 4; August–October 2005.
- Daniel Everett's Web site is available at **http://ling.man.ac.uk/Info/staff/DE/DEHome.html**



Do Self-Help Books Help?

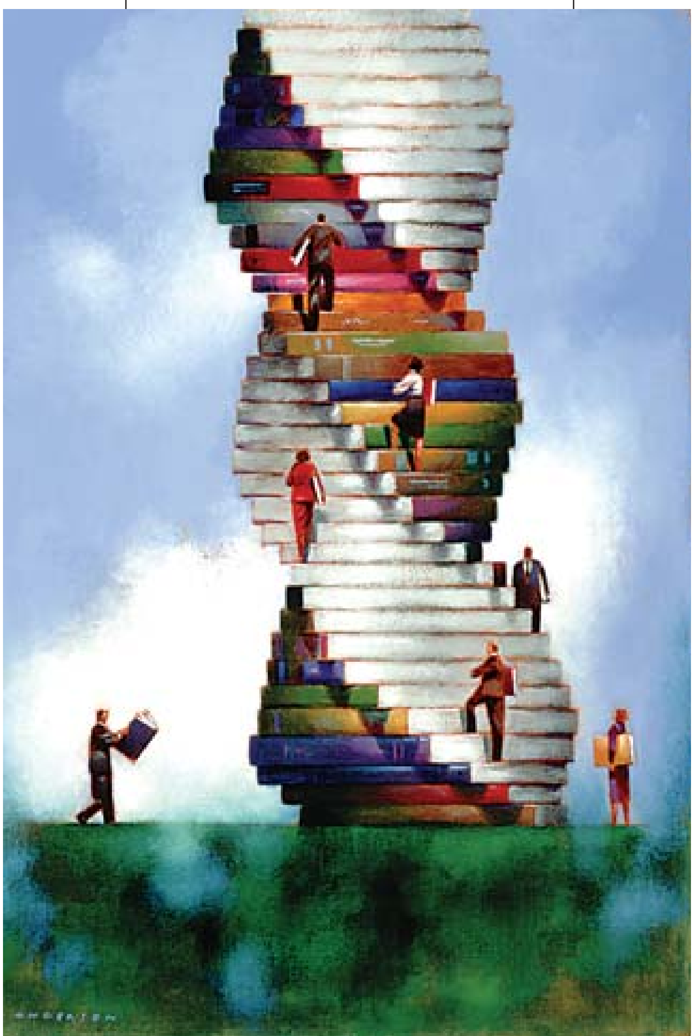
Sales are booming, but readers are not always getting their money's worth

BY HAL ARKOWITZ AND SCOTT O. LILIENFELD

HAVE YOU EVER purchased a self-help book? If so, you are like most Americans. In 2003 alone, publishers put out more than 3,500 new self-help titles, ringing up more than $650 million in sales. Many of the buyers cannot or will not seek psychotherapy, but surveys by John C. Norcross of the University of Scranton and others indicate that 80 percent or more of psychotherapists recommend such books to their patients, too. How well are self-help books fulfilling their purpose?

Authors of self-help books often make grandiose promises that invite a skeptical look. Consider the title of a best-seller by Anthony Robbins: *Awaken the Giant Within: How to Take Immediate Control of Your Mental, Emotional, Physical and Financial Destiny!* (Free Press, 1992). The dust jacket describes Robbins as an "acknowledged expert in the psychology of change." Yet he lacks any formal mental health credentials. Elsewhere, Robbins has made eyebrow-raising claims, such as that he can cure any psychological problem in a session, make someone fall in love with you in five minutes and even revive brain-dead individuals. (If he can do this with enough people, he might sell even more books.)

Even trained psychologist authors are not immune to hyperbole. Wayne Dyer, a counseling psychologist, wrote *You'll See It When You Believe It: The Way to Your Personal Transformation* (Harper Paperbacks, 2001). The dust jacket promises that "through belief you can make your most impossible dreams come true, turn obstacles into opportunities, rid yourself of guilt and inner turmoil, and spend every day doing the things you love to do." That's nice work if you can get it.



In view of how much time, money and effort buyers spend on these materials, not to mention the hopes they raise, it is remarkable how little the average person knows about their effectiveness. Moreover, as clinical psychologist Gerald M. Rosen of the University of Washington has noted, professional psychological organizations have done little to educate the public concerning the strengths and weaknesses of self-help. Still, some researchers have conducted informative studies of the effects of self-help books, or as they call it "bibliotherapy."

Typically investigators recruit participants with a specific problem (such as depression, panic attacks or obesity). They take objective measures of the problem before and after the bibliotherapy and compare such statistics with a group that gets no book or any other treatment (the "control" group); the intervening period usually lasts four to 12 weeks. Some studies also compare bibliotherapy with face-to-face psychotherapy.

Results generally demonstrate that bibliotherapy leads to greater mental health improvements than no treatment, and it often equals the benefits obtained by psychotherapy. Before you log on to Amazon.com or rush to the bookstore, however, let us describe the limitations of this research.

Small sample size. Only a tiny per-

COURTESY OF HAL ARKOWITZ (*top*); COURTESY OF SCOTT O. LILIENFELD (*bottom*); IMAGES.COM/CORBIS (*staircase*)

(Some self-help books may be unable to deliver on many of their **expansive promises**.)

centage of self-help books has been evaluated; a larger sampling may show different effects.

Minor problems. Many studies have employed subjects with relatively minor problems (such as mild fears of public speaking), which may be more amenable to self-help strategies than serious problems are.

Uneven results. Improvements occur for some but not all people, and many of those who do get better are still left with significant symptoms.

Study conditions yield greater success. Study volunteers may be more motivated than casual bookstore or airport browsers who purchase the same book. Subjects may be especially encouraged to read the book because researchers often call to monitor how they are doing. (In contrast, one of us [Arkowitz] has had a self-help book for more than 30 years entitled *How to Get Control of Your Time and Your Life*. He has not yet found the time to read it. Maybe he should take part in one of these studies.)

Combined treatments. One review found that bibliotherapy study participants also met with therapists for 36 minutes on average per week, making it difficult to separate how much of the positive effects are attributable to psychotherapy versus bibliotherapy.

False hopes. Some self-help books may be unable to deliver on their expansive promises. As a result, readers may perceive their lack of change as personal failures and even see themselves as hopeless cases ("false hope syndrome"). When unreasonable expectations for self-change go unmet, people feel frustrated and despondent and may give up trying to change.

Even when self-help works, it may not work as well as psychotherapy. A recent review by Marisa Menchola, along with University of Arizona colleague Arkowitz and Brian Burke of Fort Lewis College, examined this possibility. In contrast to previous reviews, it included only studies in which contact with a therapist or researcher was minimal and in which subjects suffered from serious problems, such as major depression or panic disorder. Overall, bibliotherapy was better than no treatment, although psychotherapy was still superior to bibliotherapy. Certain self-help books can be valuable resources for personal change—especially if readers follow some simple tips in the accompanying box. A famous Latin phrase, however, remains apt: *Caveat emptor!* ("Buyer beware!") **M**

Using Self-Help Books Wisely

- Choose books based on research or on valid psychological principles of change. See if the author makes any references to published research that support his or her claims. Some books that have been used with good effect in bibliotherapy studies are *Feeling Good: The New Mood Therapy,* by David D. Burns (Avon, 1999); *Mind over Mood: Change How You Feel by Changing the Way You Think,* by Dennis Greenberger and Christine Padesky (Guilford Press, 1995); and *Coping with Panic: A Drug-Free Approach to Coping with Anxiety Attacks,* by George Clum (Self Change Systems, 1999).
- Examine the credentials of the author. Proclaiming oneself an expert (or appearing on *Oprah*) does not an expert make.
- Be wary of books that make promises that they obviously cannot keep, such as curing a phobia in five minutes or fixing a failing marriage in a week. Typically these books are based on the personal biases and preferences of the author rather than on valid psychological principles.
- Beware of authors that offer "one size fits all" solutions. For example, a book that tells you to always express your anger to your spouse fails to take into account the complexity of the people involved and the specifics of the marriage.
- If the problem is a serious one, such as clinical depression, obsessive-compulsive disorder or schizophrenia, you are better off seeking professional treatment than reading a self-help book. *—H.A. and S.O.L.*

HAL ARKOWITZ and SCOTT O. LILIENFELD share an interest in helping the general public to distinguish myth from reality in the field of mental health. They recently wrote an article in *Scientific American Mind* about the science of psychotherapy. Arkowitz is a psychology professor at the University of Arizona, and Lilienfeld is a psychology professor at Emory University. They welcome reader suggestions for column topics: editors@sciammind.com

(Further Reading)

- **Self-Help Therapy: The Science and Business of Giving Psychology Away.** G. M. Rosen, R. E. Glasgow and T. E. Moore in *Science and Pseudoscience in Clinical Psychology.* Edited by S. O. Lilienfeld, S. J. Lynn and J. M. Lohr. Guilford Publications, 2003.
- **The Status of Self-Administered Treatments.** Edited by F. R. Scogin in special section of *Journal of Clinical Psychology,* Vol. 59, No. 3, pages 247–349; March 2003.
- **Efficacy of Self-Administered Treatments for Depression and Anxiety.** M. Menchola, H. Arkowitz and B. Burke in *Professional Psychology: Research and Practice* (in press).

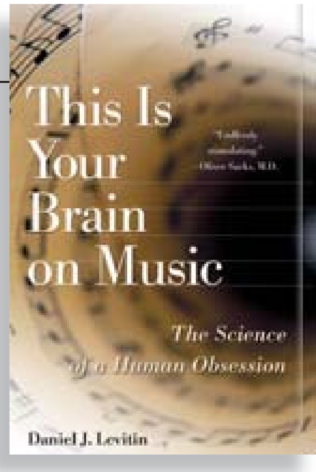
Singing His Own Song

This Is Your Brain on Music: The Science of a Human Obsession

by Daniel J. Levitin. Dutton Press, 2006 ($25)

Everyone knows that music can calm a savage beast, rouse a marching platoon or move lovers to tears. But no one knows exactly how. Daniel Levitin, a professional musician, record producer and now neuroscientist at McGill University, explains the latest thinking into why tunes touch us so deeply. He also speculates about whether specific pathways have evolved in our brain for making and listening to music.

Using brain imaging, Levitin has documented neural activation in people as they listen to music, revealing a novel cascade of excitation that begins in the auditory system and spreads to regions related to planning, expectation and language as well as arousal, pleasure, mood and rhythmic movement. "Music listening, performance and composition engage nearly every area of the brain that we have so far identified and involve nearly every neural subsystem," he notes.



Music's effects on neurons are so distributed that in some cases stroke victims who can no longer decipher letters can still read music, and some impaired individuals who cannot button a sweater can nevertheless play the piano. Levitin describes new insights into these conditions as well as disorders that cause certain individuals to lack empathy, emotional perception and musicality. He and others suspect a cluster of genes may influence both outgoingness and music ability. He also posits that music promotes cognitive development.

Not surprisingly, music reaches deep into the brain's most primitive structures—including our ancient "reptilian brain" tied to motivation, reward and emotion. Music elevates dopamine levels in the brain's mood and pleasure centers in ways similar to those triggered by narcotics and antidepressants. Levitin also explains how the neural underpinnings of auditory stimulation and mate selection reach far back in life's evolutionary scheme.

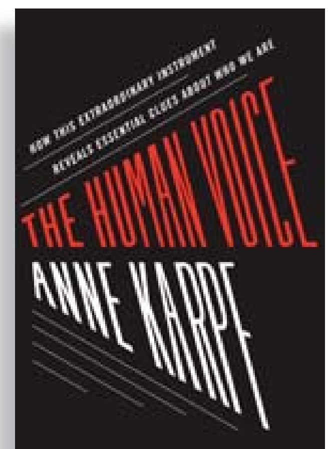
Levitin has no agenda per se, although the book is a rebuttal of sorts to scientists who say music has served no purpose other than to pleasurably stimulate auditory nerve endings. He simply explains an emerging view about the coevolution of music and the brain. To tell his tale, Levitin engagingly weaves together strands of his own life as a professional musician (who dropped out of college to form a band) with those of his transformation into a neuroscientist. To revel in Ravel's *Boléro* or Charlie Parker's *Koko,* he reminds us, is to stimulate the brain in a "choreography of neurochemical release and uptake between logical prediction systems and emotional reward systems"—a ballet of brain regions "exquisitely orchestrated." *—Richard Lipkin*

Mind Reads

More Than Simple Speech

The Human Voice

by Anne Karpf. Bloomsbury Press, 2006 ($24.95)



Despite the onslaught of text messaging, e-mail and emoticons, we still enjoy speaking to one another, if only over our cell phones. Casting the voice as an unsung hero, British author and radio broadcaster Anne Karpf challenges the notion that the visual has superseded the aural and oral. She argues that "there are three reasons for exploring the voice": it is distinctly human, vital and just plain fascinating.

Karpf begins her case by pointing out that unlike other primates for whom certain vocalizations are innate, we gradually develop our voices by learning. Humans can produce 325 sounds with vowel and pitch combinations alone. To convince us that the voice is as vital as the written word, Karpf demonstrates that words are only one color on a verbal palette that includes pitch, tone, timbre, volume and emphasis. Examples of sentences whose meanings are voice-dependent provoked this reviewer to read aloud and to think twice about the different tones with which my e-mail compositions could be read before clicking my "send" icon.

Commenting on the purely physical attributes of speech, Karpf reminds us that the voice carries as much personal data as a fingerprint; by simply analyzing a recording, future technologies may reveal our location, gender and feelings. Whether we welcome or dread "voiceprint" technology, our speech is bound to our identities and therefore to our survival.

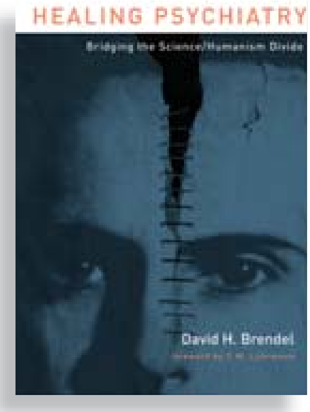
The enthusiastic author presents a pile of other fascinating facts documented in 80 pages of references. Somewhat repetitive, the book delivers catchy self-contained sections to ensure that the main points do not escape those with byte-size attention spans. Rewards await more patient readers, as Karpf explores politics and society from an acoustical angle. Her conversational and distinctly feminist style dominates sections on the philosophy behind baby talk, reasons for cultural dissonance, how voice and gender shape one another, and public speaking. Readers will develop the ability to listen rather than simply hear. *—Brie Finegold*

Down in the Swamp

Healing Psychiatry: Bridging the Science/ Humanism Divide

by David H. Brendel. MIT Press, 2006 ($26)

In his 1983 treatise, *The Reflective Practitioner,* philosopher Donald Schon explained that many professionals negotiate a tricky landscape between a high ground of theoretical questions and a swampy lowland of messy, real-life situations. The quandary is that the issues of the high ground, though easy to resolve, are relatively unimportant to most people, whereas the swamp involves matters of deep human concern. Should the practitioner remain safe or descend instead into the soup to help real people in real need?



Psychiatrists struggle with such tension daily. Practicing their profession requires theory and diagnostic definition, yet reaching a patient requires an emotional bond between the two individuals. David Brendel, an assistant professor of psychiatry at Harvard Medical School who has academic training in philosophy, explores the complexity of this tension and how it vexes modern mental health care.

"The disorder in twenty-first-century psychiatry is all about the search to integrate human values," Brendel writes. "With no objective moral or conceptual compass to orient today's practitioner, the world of clinical psychiatry remains messy and ill-defined." Despite increasing precision in biological psychiatry, he adds, "inherent limitations" of such approaches often lead to treatment shortfalls when faced with "complex and unpredictable human behavior."

Part of the solution, Brendel advises his colleagues, is to invoke a pragmatic approach espoused by the classical American philosophers William James and John Dewey. Together James and Dewey cultivated an eclectic and variegated view of scientific inquiry and discourse that aims for practical consequences for ordinary people. They emphasized the need to remain open-minded when interpreting scientific results, which always arise in a social context that shapes the nature and use of new findings.

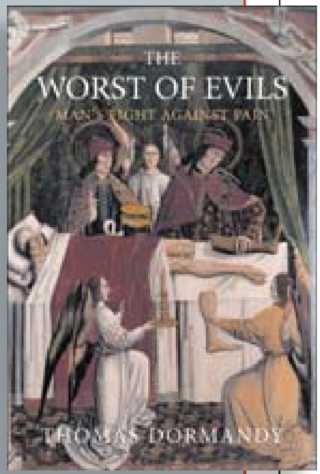
Along similar lines, Brendel advocates a "clinical pragmatism" that, for example, favors practical results over cumbersome psychological theories, decries moralistic decisions devoid of patient input, and steers clear of attributing greater certainty to clinical interpretations than may actually exist. Fleshing out his pragmatist views, he interweaves case studies with philosophical discourse and vivifies theories with clinical tales.

Brendel highlights his message with a *New Yorker* cartoon captioned "Richard the Pragmatist," in which the king proclaims: "My kingdom for a newer, stabler, more centrally located kingdom!" So, too, for the workaday practitioner, struggling to treat a patient afflicted with recurring depression or anxiety. *—Richard Lipkin*

Painful Omission

The Worst of Evils: The Fight against Pain

by Thomas Dormandy. Yale University Press, 2006 ($35)



A 560-page history of anesthesia sounds like perfect operating-room reading—you would fall asleep before page two. *The Worst of Evils,* however, is a chatty book, sprinkled with anecdotes and Thomas Dormandy's opinions—some very interesting though apropos of nothing—on everything from the French Revolution to the Iraq War. The tome is also a history of pain itself, beginning with the ideas of the ancient Greeks and Romans and ending with contemporary medical pain management.

But more than anything else, Dormandy tells the story of the men (very few women appear) who were important to the fight against pain, from Galen in Rome (who compiled medical knowledge around A.D. 200) and early Islamic thinkers to the founders of the modern hospice movement. Dormandy, a retired pathologist in London, is fascinated by the lives of the chemists, physicians and researchers who advanced our understanding of pain and the means to dull or abolish it. He tells good stories, especially when dealing with 18th- and 19th-century Europe, when science came into its own. One chapter is devoted to three generations of Renoirs—Pierre-Auguste Renoir, the impressionist painter, suffered from rheumatoid arthritis—whereas another discusses Rasputin, the evil holy man whose hypnotic powers helped to ease the pain suffered by Russian Tsar Nicholas II's hemophiliac son.

In addition to lively, clever writing, Dormandy makes several good points. He provides vivid descriptions of just how awful surgery was for doctor and patient before anesthesia. He reminds us that many religious and medical figures initially denounced anesthetics because they believed suffering ennobled patients and that pain was endorsed by the Bible. *The Worst of Evils* also has a cynical history of the rise of pharmaceuticals as big business, with aspirin leading the way.

What is missing, however, is the science. Given Dormandy's own background, how could a book with detailed histories of the introduction of ether and chloroform, the first effective anesthetics for surgery, fail to say a single word about how either chemical works? Only very late in the book does he provide an outline of the nervous system and pain perception, and except for aspirin and a few other modern medicines there is little about the chemical composition of pain drugs. Furthermore, he devotes only three paragraphs to China and India, which for centuries have had compounds to control pain.

Overall, the limitations of Dormandy's approach leave the reader disappointed, especially given the number of pages into which some of the omissions could have been painlessly woven. *—Jonathan Beard*

askthe**Brains**

> **Studies suggest that chocolate craving, especially among women, may partly result from a sense of deprivation or a reaction to stress.**

Why do we get food cravings?

—J. Shelton, Ogden, Utah

Peter Pressman of the Cedars-Sinai Medical Center in Beverly Hills, Calif., and **Roger Clemens** of the University of Southern California School of Pharmacy reply:

HANKERINGS for certain foods are not linked to any obvious nutrient insufficiency. But other biological factors appear to be at work.

Researchers have employed functional magnetic resonance imaging (fMRI) to explore the neural basis of such appetites. The imaging data suggest that when somebody is pining for a certain fare, components of the amygdala, anterior cingulate, orbital frontal cortex, insula, hippocampus, caudate and dorsolateral prefrontal cortex are activated in the brain. A network of neural regions may be involved with the emotion, memory and chemosensory stimuli of food yens.

Desire for chocolate offers an example. Constituents in chocolate may influence satiation or alter our longing for the treat by affecting mood-influencing chemicals in the brain, such as phenylethylamine, tyramine, serotonin, tryptophan and magnesium. Other foods contain these compounds at higher concentrations but tend to be less appealing than chocolate.

Some investigators have proposed that additional factors, such as simple carbohydrate content, may amplify a food's appeal or even attenuate depression. More support for a nutrition-neurological connection comes from research that shows that administration of naloxone, which blocks opiate receptors in the brain, appears to inhibit the consumption of sweet, high-fat foods such as chocolate. Studies of cannabinoids, commonly occurring in marijuana, in the brain have shed more light on the complex neurochemistry of selective appetite. In addition, research on satiety, or hunger-control mechanisms residing in the gastrointestinal tract, has led to the identification of an entire spectrum of gut neuropeptides with elaborate central nervous system feedback and influence on satiety.

Some studies suggest that chocolate craving, especially among women, may partly result from a sense of deprivation or a reaction to stress, perimenstrual hormonal fluctuation and modulation of neuropeptide concentrations. But culture has an influence as well.

Why do we yawn?

—A. Wong, Berkeley, Calif.

Mark A. W. Andrews, professor of physiology and director of the Independent Study program at the Lake Erie College of Osteopathic Medicine, provides this explanation:

THOUGH NOT FULLY UNDERSTOOD, yawning appears to be not only a sign of tiredness but also a much more general sign of changing conditions within the body. We yawn when we are fatigued and during other times when the state of mental alertness is changing.

Yawning involves interactions between the unconscious brain and the body, although the mechanism remains unclear. For many years, it was thought that yawns served to bring in more air because low oxygen levels were sensed in the lungs. We now know, however, that the lungs do not necessarily sense oxygen levels. Moreover, fetuses yawn in utero, even though their lungs aren't yet ventilated. In addition, different regions of the brain control yawning and breathing. Still, low oxygen levels in the paraventricular nucleus (PVN) of the hypothalamus of the brain can induce yawning. Another hypothesis is that we yawn because we are tired or bored. But this, too, is probably not the case, because the PVN also plays a role in penile erection, which is not typically an event associated with boredom.

The PVN of the hypothalamus is the "yawning center" of the brain. It contains chemical messengers that can induce yawns, including dopamine, glycine, oxytocin and adrenocorticotropic hormone. The process of yawning also appears to require production of nitric oxide by specific neurons in the PVN. Once stimulated, the cells of the PVN activate cells of the brain stem or hippocampus, prompting yawning.

Seeing, hearing or thinking about yawning can trigger the event, but there is little understanding of why. Some evidence suggests that yawning is a means of communicating to others changes in environmental or internal body conditions, possibly as a way to synchronize behavior. If this is the case, yawning in humans is most likely vestigial and an evolutionarily ancient mechanism that has lost its significance. **M**

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

COURTESY OF PETER PRESSMAN (*top*); COURTESY OF ROGER CLEMENS (*bottom*); COURTESY OF MARK A. W. ANDREWS (*center*)

Head Games

Match wits with the Mensa puzzler

BY ABBIE F. SALNY

1 Figure out the logic in the lines below and fill in the missing number.

9 3 3 ▯ 8 2 4

25 5 5 ▯ 16 4 ?

2 An interesting point is coiled in the grid below. Start at the correct letter and move in any direction to find the saying. (Hint: start with a "Y.")

E	E	D	A	O	D	M	E
N	T	S	G	O	V	A	M
O	N	E	I	R	E	H	O
D	U	E	M	O	G	O	R
Y	O	M	D	O	O	T	Y

3 You walk to your friend's house at three miles per hour, ring the bell and realize he's not home, and walk back at four miles per hour. The round-trip took 21 hours. How far did you walk?

4 A man goes into a hardware store and asks, "How much for one?" The clerk replies, "$1." "Okay," the customer says. "I'll take 150. Here's $3." What did he buy?

5 The following familiar line has been turned into a simple substitution cryptogram. Solve the cryptogram.

U I J T J T B T J N Q M F D S Z Q U P H S B N

6 Rearrange the same seven letters to find two words that can fill in the blanks below.

The young mother _ _ _ _ _ _ _ to be a writer, but changing _ _ _ _ _ _ _ took up so much time, she did not have time to work.

7 Here is a two-part question.

First, start with a word that means "the cause." Now change the first letter and find a word that means "part of the year."

Second, take a word that means "walk heavily." Change the first letter to find a word that means "to do monotonous work."

8 The following 14 letters can be rearranged into a four-word phrase that mentions a geographic location and means "very quickly."

A E E I K M N N O R T U W Y

9 Find the word that fits the definitions on each side of the line.

Part of a human _____ Pay attention

An animal _____ Put up with

A geographic term _____ A piece of clothing

10 What is the five-digit number in which the first digit is one more than the second, the last is four fewer than the first, the second is more than the last, and the fourth is one more than the last? The sum of all the digits is 35.

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

1. 4. Multiply the number on the right and the number in the middle to get the first number.
2. "You don't need a good memory to have good memories."
3. 72 miles. It is 36 miles each way, and it takes 12 hours for the trip out and nine hours for the return.
4. House numbers.
5. "This is a simple cryptogram." (Move up one letter.)
6. Aspired, diapers.
7. Reason, season; trudge, drudge.
8. "A New York minute."
9. Mind, bear, cape.
10. 98,765.

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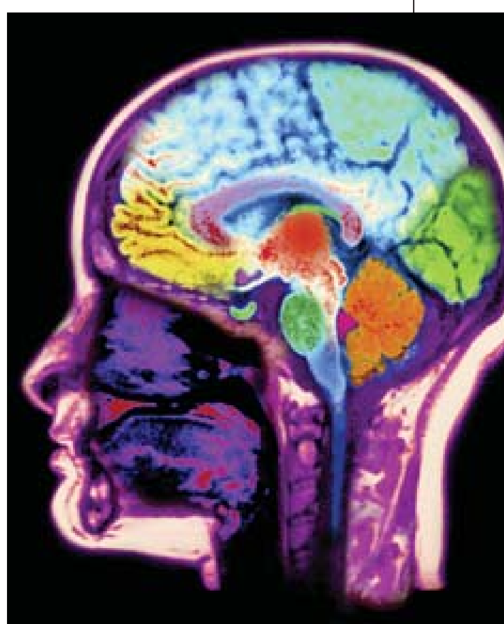

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It Takes Two . . . ▲

... to tango, paddle a large canoe or move a heavy box. Now science is learning how people act smoothly in concert.

Guilty Brains ▶

Courts are looking at using brain scans as evidence in trials. But can we trust such images to be accurate?

Sleepless in Stages

Breaking a night's rest into two pieces may not be a sign of insomnia but of a natural sleep pattern that is bubbling to the surface.

Misery of Migraines

The excruciating pain appears to arise from mechanisms that differ from run-of-the-mill headaches. What can be done about migraines?