THE EXTRASENSORY DECEPTION OF SYNESTHESIA

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Lust for Danger:
Why We Gamble
and Have Affairs

DISPLAY UNTIL NOVEMBER 21, 2005

The Chaos of Consciousness

How the brain creates reality

Hearing Colors, Tasting Shapes

Smarter on Drugs?

The Psychology of Tyranny

Spinal Cord Repair

Bright Cures for the Blues

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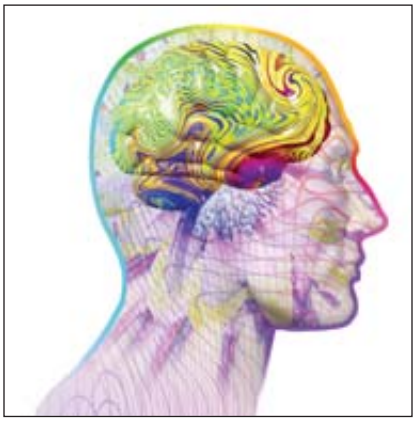
JEAN-FRANCOIS PODEVIN



Sense and Sensibility

You could call it one of the most magnificent conundrums of our existence: consciousness. How can an experience be so routine, so common to all of us—and yet so utterly unfathomable at its deepest levels?

That enigma has long intrigued neuroscientists such as Christof Koch, author of the cover story, "The Movie in Your Head." Imaging technology reveals what areas in the brain are buzzing with neural activity when a person is tracking a speeding car, looking at a loved one or eating a chocolate bar. But how does such incessant chemical signaling stitch fleeting sensory impressions into an apparently seamless stream of consciousness? Is the "real world" we know merely an illusion created from those fragments? The show starts on page 58.

Clues about the processing of complex sensory inputs also come from brains that are not "normal." For people with synesthesia, for instance, sight, hearing and touch can blend in extraordinary ways. The sound of each note plunked on a piano might evoke a different color. Printed letters, words, numbers or even days on a calendar may gleam with hues of their own. Flavor can mingle with shapes. The strains of a violin can feel like a caress.

The condition confers a unique gift not only on people who experience its wonders firsthand but also on researchers. In "Hearing Colors, Tasting Shapes," beginning on page 16, neuroscientists Vilayanur S. Ramachandran and Edward M. Hubbard describe insights they have gleaned from synesthesia's exotic world.

A vivid sensory rush also underlies humanity's shared "Lust for Danger," as Klaus Manhart explains, starting on page 24. We crave the pleasurable thrill of risk taking—whether that excitement comes from betting it all in a game of Texas Hold 'Em, watching a suspenseful horror movie or parachuting out of an airplane. The success of our forebears, early human adventurers, gave them a survival edge that remains part of our collective mental hard wiring.

Seeking sensible feedback to refine our own *Mind*, we invite you to join our panel of reader advisers. Interested? Sign up at www.sciam.com/feedback/

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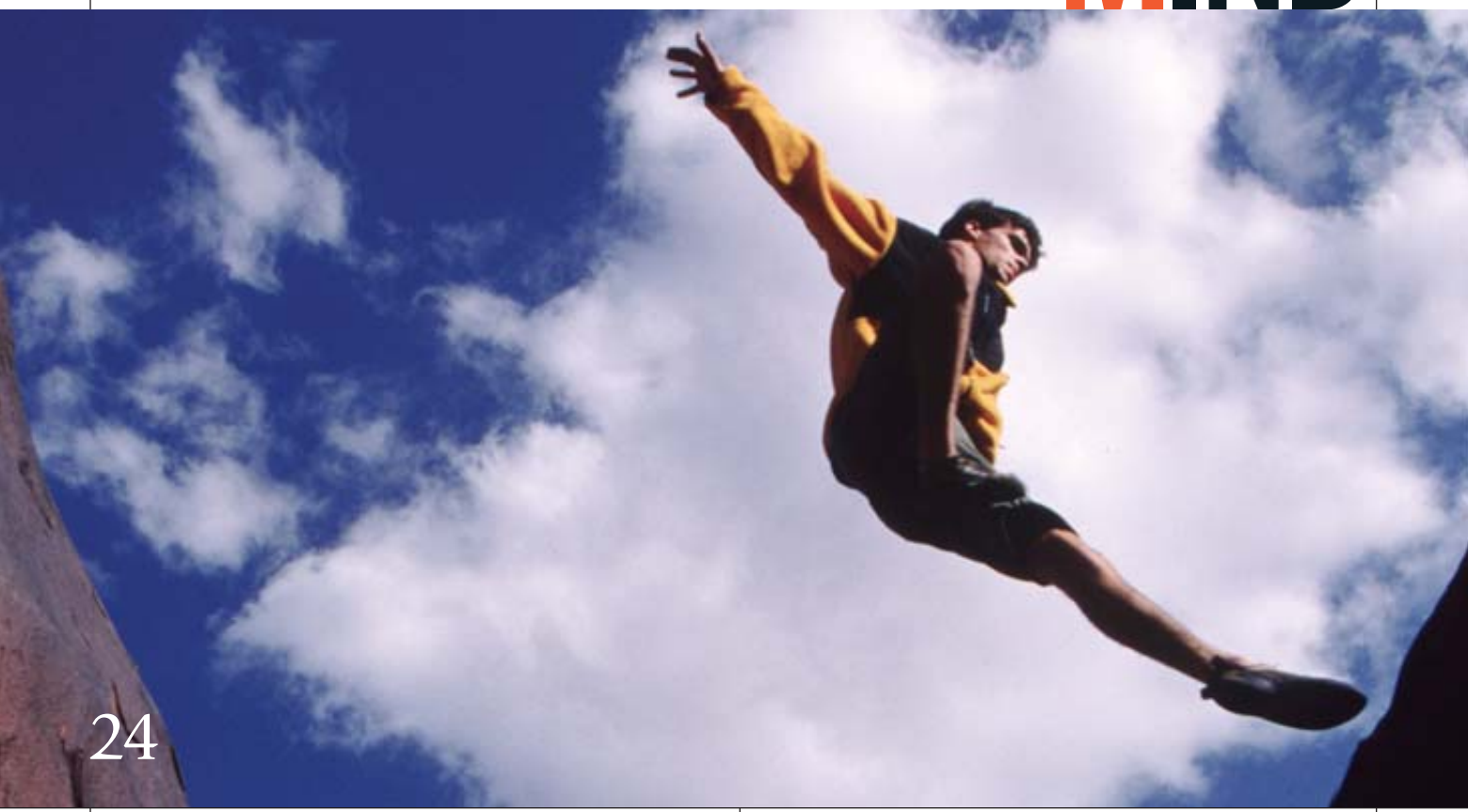
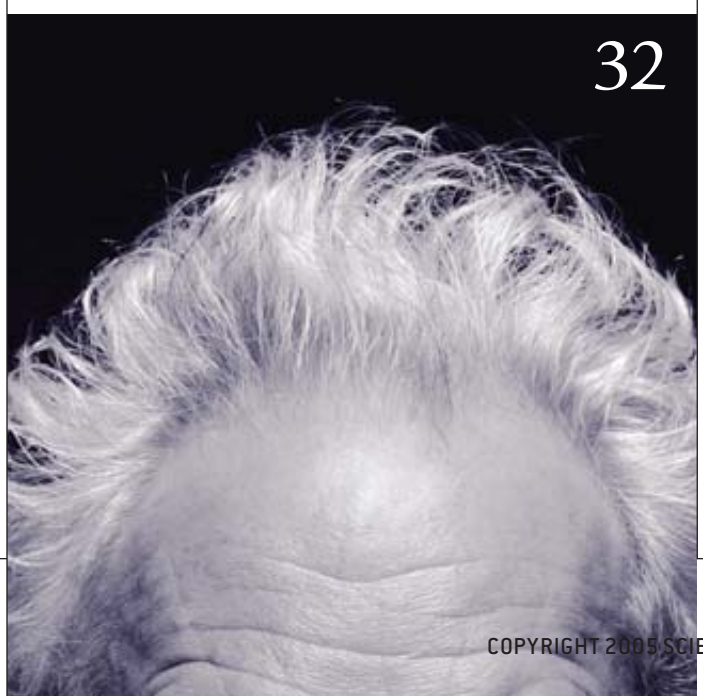


FEATURES



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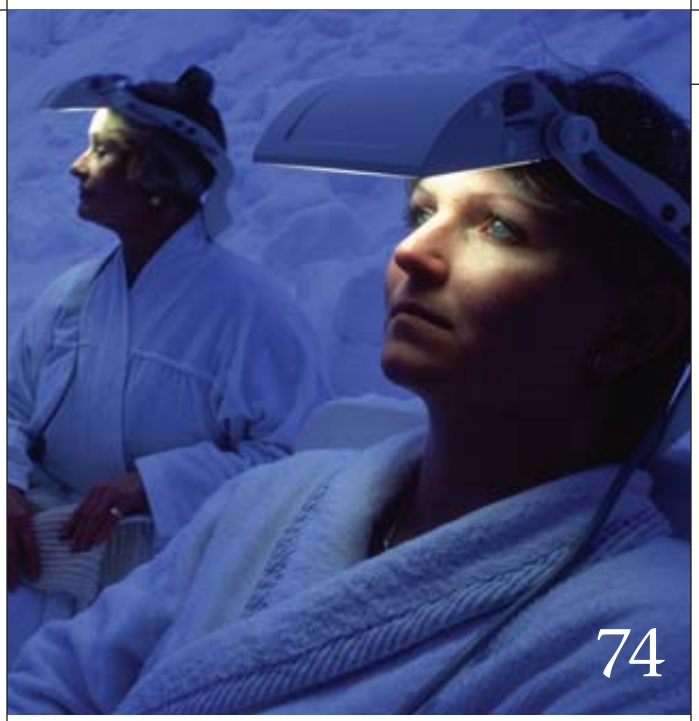

DEPARTMENTS

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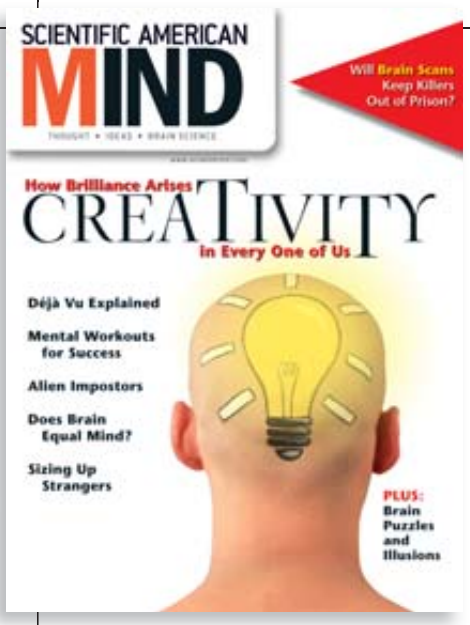
BRIGHT IDEAS shone forth on many pages in *Scientific American Mind* issue Number 1 for 2005, starting with the image on the cover itself. "Unleashing Creativity," by Ulrich Kraft, offered suggestions for tapping the inner muse. David Dobbs's "Fact or Phrenology?" explored the search for the mind arising from the activity of intricate physical mechanisms in the brain. "Neuroscience and the Law," by Michael S. Gazzaniga and Megan S. Steven, posited that a better understanding of the mechanisms underlying behavior could absolve criminals of fault—something to think about. More about these topics—and others—follow below for readers with curious minds.



CREATIVE RESPONSES

Ulrich Kraft's "Unleashing Creativity" confuses artistic ability with lateral thinking. There is a difference between "thinking outside the box," which is really the subject of Kraft's discussion, and innate artistic abilities, such as drawing, musicianship or creative writing, which require genetic inheritance as well as a cultural environment to develop. Kraft equates creative problem solving with artistic skills, but they are different entities that sometimes coexist.

Paul Mealing
Melbourne, Australia

I fully agree with Kraft that creativity is often lost during the first 20 years of development. To encourage creativity, my friend Paul Aron and I have been working for more than two years on an online gallery called TheRightBrain—it is our attempt to enrich the right hemispheres of many in the medical profession: www.therightbrain.co.uk

Graham Campbell
via e-mail

BRAIN AND MIND

The cover promised a discussion of "Does Brain Equal Mind?" but in the article "Fact or Phrenology?" David Dobbs discusses the rather narrow aspect of fMRI. Everyone approaching the subject of brain-mind from a scientific stance takes for granted that the mind arises from activity in the brain. That activity consists of far more than certain regions consuming more or less oxygen than others. Rather it is what is actually going on in and between those regions at the fine level of individual neurons and synapses that is important—and we do not understand those processes at all, as other *Scientific American Mind* articles have made abundantly clear. How the almost infinite complexity of the brain gives rise to any aspect of mind is a near-total mystery and likely to remain so for a long time.

Imaging can certainly give interesting clues. But using MRIs to learn how the brain—much less the mind—actually works is like studying human civilization solely by recording patterns of electrical consumption across the globe. That critique aside, the controversy over MRIs barely touches on the subject of the relation between brain and mind.

"Everyone approaching the subject of brain-mind from a scientific stance takes for granted that the mind arises from activity in the brain."

The essay on "Neuroscience and the Law," by Michael S. Gazzaniga and Megan S. Steven, is also disappointing for its once-over-lightly treatment of the question of free will in the light of the deterministic stance of neurophysiology. Particularly surprising is the omission from the Further Reading of *The Illusion of Conscious Will*, by Daniel M. Wegner, a Harvard University professor of psychology. To oversimplify Wegner, free will is best understood as an emotion. Like all emotions, it has an inescapable psychological reality, no matter what its presumed underlying neurophysiological cause. There is no conflict between scientific determinism and free will any more than there is a conflict between determinism and the fact that people fall in love.

Peter Kassan
Dobbs Ferry, N.Y.

Gazzaniga and Steven may be right to argue that moral responsibility is a

human construct and not a physical property of the brain. Just as it is a mistake to argue that metals are not hard simply because their constituent molecules are not themselves hard, so it is also a mistake to argue that people are not responsible simply because responsibility is not a property of our neurons.

But it does not necessarily follow that neuroscience has no contribution to make. After all, a metal's macro hardness does depend on micro facts about its structure. Just because the two levels are distinct does not mean they are not closely linked. Might not society's notion of responsibility similarly depend on physical presuppositions about our physical brains—such as, say, nondeterminism—which neuroscience is in a perfect position to illuminate?

Toby Wardman
York, England

DREAMS OF DÉJÀ VU

"Strangely Familiar," by Uwe Wolfradt, about déjà vu made no mention of those instances in which one has a dream and then, at a later point, gets the déjà vu feeling. I personally have dreams of events or instances and then get the déjà vu feeling at a later date, and it is absolutely identical to the dream.

Faiyaz Mohammed
Elk Grove, Calif.

PROBLEMS FOR PRODIGIES

Regarding "Watching Prodigies for the Dark Side," by Marie-Noëlle Ganry-Tardy: somehow there is an idea that a child with an IQ of 50 needs special support and provision from appropriately trained staff but that at the other end—an IQ of 150 and beyond—children will muddle through with a spot of differentiation by a busy teacher, no assessment and no extra money. I know because one of my sons is a prodigy.

The inadequate provision and isolation he experienced in school would make you cry. In the end he switched off; his teachers thought he might have

CORBIS

Youthful brilliance can often come with a steep emotional price.

"one or two talents" but was "nothing special." After a secondary school teacher came to work with him at school, all of a sudden he was "profoundly gifted" and all the rest. That is, for those five hours a week; the rest of the time he was disengaged, isolated and undermotivated. Ultimately we moved him to a selective school with the staffing ratios and facilities to address his needs.

If you fight for provision for your low-IQ child, you are a hero; for your high-IQ child, a pushy parent. There is very little understanding and help. The word "gifted" itself takes your breath away. Who says being abnormal (especially when very young) is a gift?

Sarah Yates
via e-mail

OCCULT DEFINED

Reader Erik Gfesser in the Letters section improperly demands special privilege for Christianity when he criticizes Gunther Klosinski's "Casting Out the Demons" for treating magic and the Holy Spirit as "occult." Klosinski's grouping appropriately reflects my dictionary's definition of occult, however: "Of, relating to, or dealing with supernatural influences, agencies, or phenomena." On that basis, faith in the Christian God is no less occult than faith in Shiva, Baal, Thor or witchcraft.

Science is an inherently secular pursuit in which no transcendental belief system is privileged, whatever its status in the larger culture. *Scientific American Mind* reports on, and should to some degree reflect, a scientific community that by a substantial margin finds neither Christianity nor any other supernatural belief system compelling.

Tom Flynn
Editor, *Free Inquiry* magazine
Amherst, N.Y.

PERFECT SCORE?

I thoroughly enjoyed the latest issue of *Scientific American Mind*. But I disagree with question 8 in Head Games, which asks the reader to find which word in line two best belongs with the words in line one. The answer provided is the word "hamburger." But "always" is also correct, because it is the only two-syllable word in line two and all the words in line one are two-syllable words. That makes question 8 invalid—and it was the only one I missed in what was an otherwise perfect score!

Tom Baird
via e-mail

Head Lines

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Panicky Hot Spots

Millions of people—some 2 percent of the U.S. population—experience panic attacks, characterized by sudden fear accompanied by rapid heartbeat, nausea, shaking, numbness, hyperventilating or sweating. Many end up in emergency rooms, believing they are having a heart attack. What is more, one third of patients who visit a cardiologist with atypical chest pain actually suffer from unrecognized panic disorder.

Now scientists are trying to identify genetic markers that could help predict who is prone to the terrifying condition and provide a possible avenue for new drugs that could alleviate symptoms.

To reach this goal, researchers at Columbia University College of Physicians and Surgeons are taking a two-pronged approach: tracking genes in panicky animals and hunting for similar genes in people with varying degrees of fear. Recent animal tests point to interesting hot spots on several chromosomes. Their locations have led Columbia epidemiologist Myrna Weissman and Nobel laureate Eric R. Kandel of the school's Center for Neurobiology and Behavior to look for genetic markers in human volunteers. Other investigators have linked two genes, *COMT* and *Adora2A,* to panic disorder in people. Dozens more genes could be involved. "There is definitely a strong genetic component," Weissman says. Individuals with a close relative suffering from panic have a fivefold increase in risk.

Having genes in hand will help unravel the syndrome's biochemical causes and aid in diagnosis. Currently the average victim sees 10 physicians before getting a correct diagnosis.

—Jamie Talan

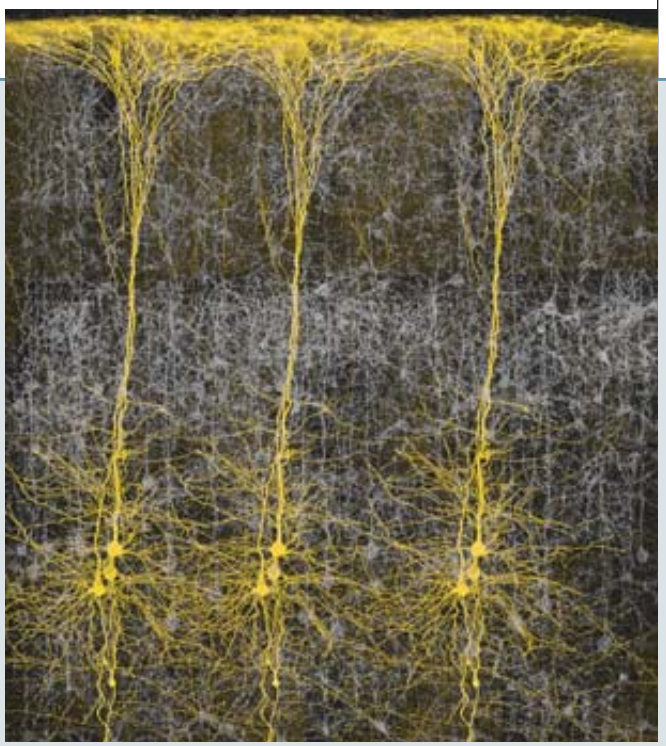
Big Blue's Neocortex

Probing the human brain directly presents great medical and ethical hurdles. Researchers' efforts are also often stunted by limitations imposed by imperfect models. That latter restriction, at least, may soon ease: IBM recently announced plans to build a digital model of the brain.

IBM's Blue Gene, regarded as the world's most powerful supercomputer, will be used over the next two years by company researchers, in collaboration with the Brain Mind Institute at the Swiss Federal Institute of Technology in Lausanne, to simulate the electrochemistry of the neocortex—the large part of the brain responsible for cognition. The goal is to understand perception, learning and memory. The Blue Brain Project model could also perhaps improve our knowledge about mental disorders, such as autism and schizophrenia.

The effort is not the first to create a computational model of the human brain, but it appears to be the most extensive. "This type of endeavor at this number of circuit elements, with the capacity to include realistic properties, has never been attempted before," says Yale University neurobiologist Gordon M. Shepherd, who is not involved in the project.

IBM's human brain model, if successful, will surely prove to be useful. But many neurobiologists agree that Blue Brain will not be a substitute for traditional research. "While mathematical simulations are extremely helpful and predictive for hypothesis testing," advises Jeffrey T. Potts, a neurobiologist at the University of Missouri not on the Blue Brain team,



Output neurons (*gold*) along neocortex neurons (*white*) are to be modeled.

"they will not replace the physiological elegance and complexity of biological life, be it mice, cats, dogs or humans."

— Kiryn Haslinger

A Jewish Gene for Intelligence?

Although the Holocaust was propelled by charges that Jews were genetically inferior to Aryans, a new study in the *Journal of Biosocial Science* published online in June supports the opposite notion: Ashkenazi Jews may be genetically predisposed to higher intelligence.

In the past, powerful figures, including Adolf Hitler, manipulated pseudoscientific ideas to fuel prejudice. But legitimate biological techniques now allow researchers to identify the functions of specific genes. Gregory Cochran, the infamous independent evolutionary biologist who in 1992 proposed that homosexuality is caused by an infectious disease, has teamed up with anthropologists Henry Harpending and Jason Hardy of the University of Utah. They claim that Ashkenazi Jews—an ethnic group that includes physicist Albert Einstein, psychoanalyst Sigmund Freud and composer Gustav Mahler—are more intelligent because of genetic mutation.

Sigmund Freud (*left*), Albert Einstein and Gustav Mahler may have had special IQ genes.

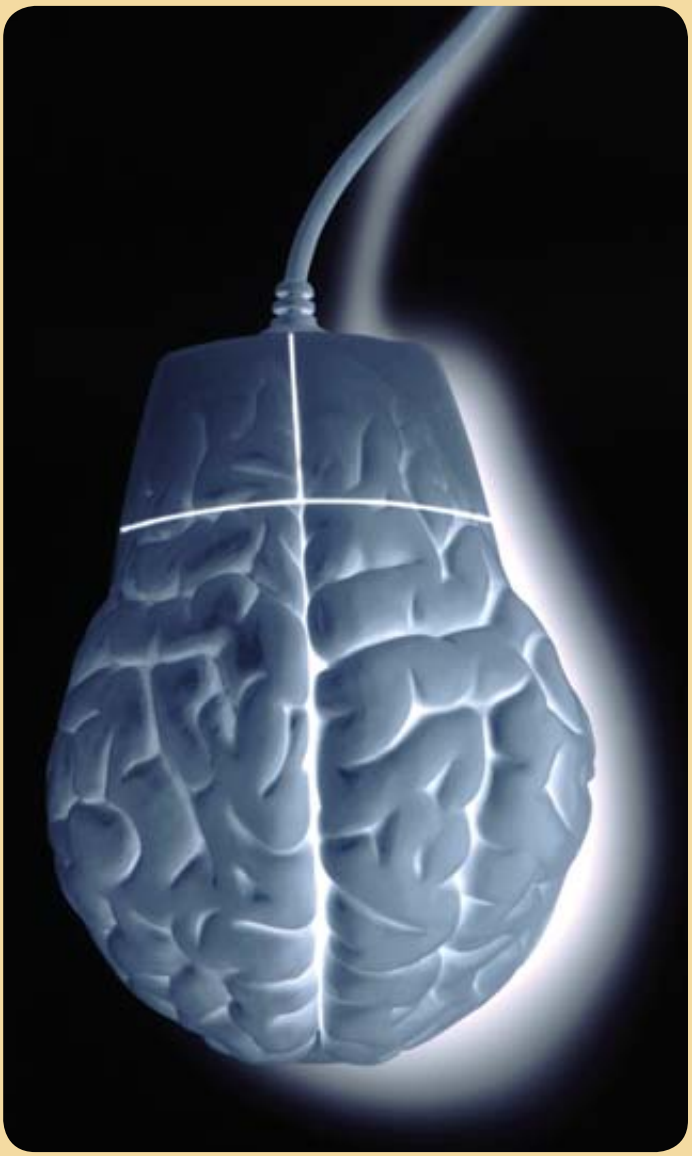
"People would like every group to be exactly the same," Cochran says, "but they're not." The study claims that intelligence evolved in this genetically isolated population because, historically, Ashkenazim had cognitively demanding occupations such as financiers and merchants. Prowess in these fields provided prosperity and, so the theory goes, more success in reproduction. Thus, the "IQ gene" passed down through generations.

At the same time, the researchers noted that genetic diseases common to the group, including Tay-Sachs and Gaucher's, result from increased levels of a chemical that also promotes neuronal growth. After assessing the genetic clustering of mutant genes and correlating these with IQ scores, the researchers contend that the genetic diseases are linked to a propensity for greater intelligence. The survival edge conferred by higher IQs in the group makes up for individual penalties from the diseases.

Most scientists insist that cultural factors play critical roles in the development of a person's intelligence. But Cochran is convinced that across generations, a person's environment is insignificant compared with strong biological factors. "As genetics marches on, there are a lot of things people think are cultural, and they're turning out not to be," he says.

The sordid history of mixing genetics, ethnicity and intellect guarantees a spotlight on this work. But only time and rigorous research will tell if genes are the most important factor in conferring smarts. *—Kiryn Haslinger*

IBM RESEARCH (*top*); BETTMANN/CORBIS (*Freud*); DEBORAH BETZ *Corbis* (*Einstein*); MICHAEL NICHOLSON *Corbis* (*Mahler*)



Computer-Aided Brains

For years, innovators have tried to devise computerized gadgetry to aid the brain. Advances have come slowly, but new work unveiled in recent months has sparked enthusiasm.

Computer scientist Roel Vertegaal of Queen's University in Ontario has crafted headphones that replicate the brain's unconscious noise filter, which handles the so-called cocktail party effect. In a crowded setting, two people in a conversation use eye contact to help them focus on each other's words and tune out background noise. Vertegaal's "attentive headphones" have a camera attached to an accompanying computer that tracks a person's gaze as a cue for interaction. The technology could one day help people in trains and in coffee shops work on their laptops more productively by minimizing the effects of distractions.

At Microsoft Research in Redmond, Wash., psychologist Mary Czerwinski has tested a prototype of a helmet that, as she says, "projects infrared light into the brain from the scalp and measures optical changes as the light is reflected back out." The manufacturer, Archinoetics in Honolulu, developed the wireless helmet for the military to try to gauge a soldier's mental workload, helping him or her act on reason rather than impulse in tense situations. Czerwinski foresees consumers possibly using such headgear to navigate shopping malls and supermarkets. At demos, individuals are sometimes wary about donning the helmet, but Czerwinski says resistance to such interactive hardware is waning as people adopt wearable technology, such as heart rate monitors.

Other advances could make driving safer. At Drexel University, computer scientist Dario Salvucci has developed a computer model that predicts how a driver's concentration on the road may be compromised by other cognitive tasks, such as listening to the radio or talking on a cell phone. Car companies have been trying Salvucci's software, along with a driving simulator, as a test bed for new accessories that do not distract drivers.

—Brad Stenger

Cheese or body odor? Whether a scent seems pleasant depends on its label.

Ooh, That Smell

A rose by any other name might not smell as sweet. Edmund Rolls, a psychologist at the University of Oxford, has found that cognition—high-order brain processing—can influence perception of smell at its most primitive level.

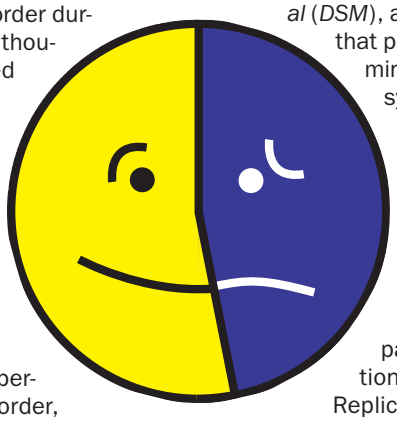
Rolls presented 12 subjects with an ambiguous odor, which he says "might have been thought to be Brie" but was labeled either "cheddar cheese" or "body odor." Subjects rated the smell as much more pleasant when it was labeled cheese. In magnetic resonance images, brain regions involved in early olfactory processing were activated more strongly by the positive label. "The big conclusion," Rolls says, "is that language can reach right down into the emotional system."

—Kaspar Mossman

JOHN LUND *Corbis (top)*; CONNIE COLEMAN *Getty Images (bottom)*

Half Are Mentally Ill

It has been a decade since scientists last fanned out across the country to assess the rates of mental illness. The latest census, just completed, indicates that a whopping 46 percent of Americans will suffer from a mental disorder during their lifetime. Tens of thousands of people answered questions about their deepest thoughts and behaviors for the study, the most extensive ever conducted.



In any given year, 18 percent of respondents suffered from a serious anxiety disorder, 10 percent from depression or bipolar illness, 9 percent from an impulse disorder, and 4 percent from alcohol or drug addiction. "This is depressing," says Harvard University epidemiologist Ronald C. Kessler, who directed the huge study, which was published as a series of papers in the *Archives of General Psychiatry.*

The findings also speak volumes about treatment. Only 40 percent of those who researchers deemed would have qualified as mentally ill said they had received some kind of treatment, and often that was from someone other than a mental health provider. "We have to figure out how to improve the quality of the care these patients receive," Kessler says.

The prevalence of problems is much greater than that reported 20 years ago, when the first survey of this scope was carried out. Those results prompted an overhaul of the *Diagnostic and Statistical Manual* (*DSM*), a massive tome of criteria that psychiatrists use to determine whether an individual's symptoms qualify as a clinical illness. The updated fourth edition, known as *DSM-IV,* has been the bible since, but it may need to be revised again in light of the new data.

In total, more than 15,000 Americans have participated in the two National Comorbidity Survey Replication studies, which Kessler also led in 1994. Perhaps the only good news is that most clinical cases are mild and that only a small proportion are severe. But most people said that the first signs of their illness appeared before age 18, arguing for more extensive treatment of young people. Kessler's small research army is now analyzing an additional 10,000 adolescents and performing separate studies of African-Americans, Hispanic-Americans and Asian-Americans to look for more specific trends.

—Jamie Talan

The Dreaded Middle Seat

On commuter trains, the middle seat in a bank of three is always the last to be occupied. Some passengers will even stand for an hour by doorways rather than sit between patrons. Why? This quirky aversion may be a case of psychological security trumping physical comfort.

The tension often begins when greedy window- and aisle-seat occupants discourage access to the middle seat by blocking it with a briefcase or studiously avoiding eye contact with approaching seat searchers. Many passengers would sooner walk by than initiate a strained interaction.

And if a commuter does squeeze in, the trials continue. According to Richard E. Wener, an environmental psychologist at Polytechnic University in Brooklyn, unplanned encounters such as brushing an arm against a neighbor raise anxiety by marring one's sense of "predictability and control." (For more on travel stress, see "Commuting Takes Its Toll," on page 14.)

The phobia has become so prevalent that as transit authorities from Washington, D.C., to Seattle update their fleets, they are commissioning cars containing only pairs of seats, even if that means more cars per train or that more commuters must stand. No one has really examined how to reduce the problem, but Wener offers one suggestion: armrests, like those on airplanes. "These help each traveler demarcate territory," which fosters a perception of increased control, lessening stress.

—Andrew Marantz

BRIEFS

- **Wild animals freeze**—like deer in the headlights—when they sense a predator, making them harder to spot. This automatic response persists in humans. Eliane Volchan of the Federal University of Rio de Janeiro in Brazil observed the "freezing reaction" in 48 male volunteers. When shown disturbing pictures of mutilated bodies, the men instantly stopped moving and their heart rates dropped. They were scared stiff.

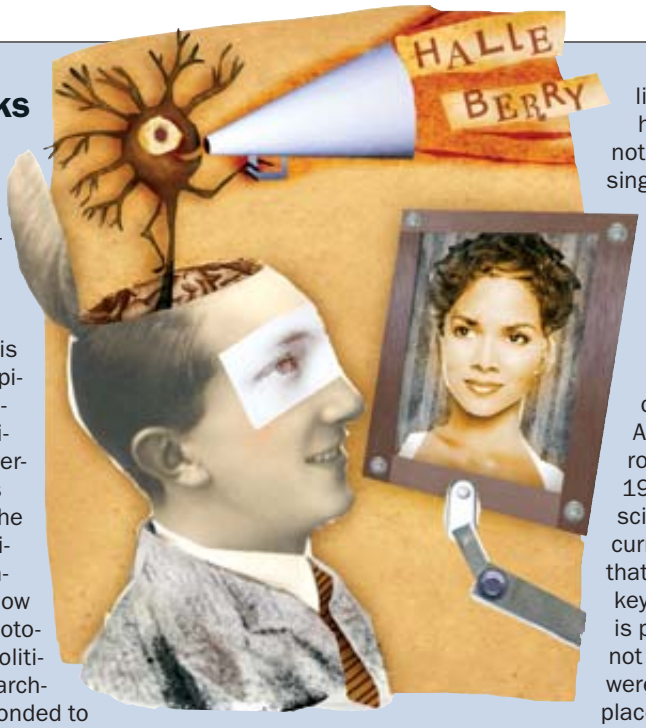
- **The work that piles up** before and after a vacation causes so much stress it can cancel the mental health benefit of the getaway. To prevent this problem, Joshua Klapow of the University of Alabama at Birmingham recommends neatly tying up tasks before you leave; on returning, pace yourself as you work through the backlog.

- **Even seven-year-olds** see that someone might lie to win advantage, but not until age 11 do children understand that a person's background might lead to unintentional bias. Candice Mills of the University of Texas at Dallas told 80 youngsters ages five to 11 stories in which characters made claims in their favor. Only the eldest recognized that such wrong statements might be unintentional because of unconscious predisposition.

- **In tests by** Robb Willer of Cornell University, men accused of being insecure about their masculinity voiced fervent support of the war in Iraq and sport utility vehicles, confirming a Freudian tenet: men overcompensate to prove their machismo.

SCIENTIFIC AMERICAN (*top*); SUSAN STAVA *The New York Times* (*bottom*)

Single Neuron Speaks



A lone neuron in one of the brain's key memory centers may be able to distinguish a specific person or place, negating a long-standing tenet that a group of neurons is needed to encode any memory.

The single-neuron hypothesis comes from a recent study of epilepsy patients. A team led by researchers at the California Institute of Technology and the University of California at Los Angeles implanted small electrodes in the epileptics' brains to monitor seizure activity. The patients volunteered to watch a rapid slide show of random images, including photographs of famous landmarks, politicians and celebrities. The researchers found that single cells responded to single images, by sorting neural activity based on the cells' unique timing and response characteristics.

One patient had a neuron that responded to a photograph of actress Halle Berry but not to images of other actresses. The same neuron fired when the patient was shown line drawings of the actress or her name typed on a screen but not other drawings or names. A single neuron in another patient responded to photographs and words denoting the Sydney Opera House but not other landmarks.

The experiments advance work the group started two years ago that prompted media discussion of a Bill Clinton gene. Although the single-concept neuron theory dates back to the 1960s, it had been dismissed by scientists. Itzhak Fried, one of the current investigators, suggests that one-to-one correlations may be key to efficient memory storage. It is possible, however, that neurons not monitored during the procedure were responding to the people or places presented. Conversely, some neurons fired when two different images were presented. Co-investigator Rodrigo Quian Quiroga suggests this might occur if we "associate one particular person with one particular object and we want to store this association in long-term memory." *—Nicole Garbarini*

Hungry for Love

His face is her reward.

The rush we feel when newly in love is not an emotion. It is a reward produced by ancient brain pathways that similarly motivate eating and drinking, according to a new, multi-institute study. The results indicate that during the intoxicating early stages of a relationship, "we are driven," says Lucy L. Brown, a neuroscientist at the Albert Einstein College of Medicine and a co-author of the study. "The person we are in love with becomes a goal in our lives."

Brown and her colleagues recruited 17 subjects who were 18 to 26 years old and had been smitten for one to 17 months. The researchers used functional magnetic resonance imaging to see how the subjects' brains responded to a picture of their beloved, in contrast with an image of an acquaintance. For every lovebird, gazing at his or her sweetheart activated the unconscious neural system associated with reward, which arose early in mammalian evolution to encourage vital behaviors. Other neural activity varied; for example, some individuals who had been in love for more than eight months had stronger signals in cortical areas involved in cognition and emotion.

Brown concludes that early romantic love is not an emotion but a motivational state. The brain encourages an intense focus on the beloved through the reward system. Then, thanks to the many neural systems linked to our reward circuitry, we experience other feelings. "When you are in love, you can be anxious, happy, sad or angry," Brown says, "but you still have a core feeling of loving the person."

Eventually Brown would like to follow relationships that last for years, to understand what happens "when people form attachments and what goes wrong when people don't," she explains. In the meantime, her group is studying personal rejection by showing subjects a picture of a recent ex-boyfriend or ex-girlfriend, which Brown notes "is not so rewarding."

—Aimee Cunningham

Think Ensemble

The brain does not function linearly, as most computers do. Instead groups of neurons compete to represent a concept, until one emerges dominant. The mind consists of an ensemble of such states, continuously evolving and sharing information. Michael Spivey, a psychologist at Cornell University, recently presented one more piece of evidence for this conclusion.

The researcher asked 42 volunteers to move a cursor toward one of two images at the top of a computer screen after hearing a recorded voice speak the name of one of them. When the two objects had phonetically similar names, such as "candle" and "candy," the volunteers took longer to click on the correct object than when the names were distinct ("candle" and "jacket"). Furthermore, the cursor trajectories were more curved when the words sounded similar. The curvature represents the time during which the two interpretations are competing, before one finally wins out, which Spivey says, "argues against the traditional modular framework"—the model in which the mind works like a computer.

—Kaspar Mossman

ISABELLE CARDINAL (*top*); M. MÖLLENBERG *zefa/Corbis* (*bottom*)

Engaging in conversation, not handling the phone, distracts the driver.

Hang Up and Drive

We can walk and chew gum at the same time without bumping into utility poles. So what is the big deal about driving while talking on a cell phone?

Plenty. Investigators from the University of Sydney, the University of Western Australia and the Insurance Institute for Highway Safety in Arlington, Va., recently analyzed accident data and cell phone records of 744 drivers in Perth. They concluded that yakking drivers are four times more likely to crash their cars. And using a hands-free headset instead of a handheld phone made no difference at all. Several cities and states have forbidden the use of handheld, but not hands-free, phones in moving vehicles.

Independent studies confirm the risk and suggest that it is engaging in conversation, not manipulating a phone, that is most distracting. That argument you are having with your girlfriend over your hands-free phone is tying up neurons that could be better used to keep your Subaru between the lane lines. Experiments by Johns Hopkins University psychologists Sarah Shomstein and Steven Yantis on 11 volunteers show that the brain can be intensely aware of what is coming through either the eyes or the ears but not both at the same time. The subjects watched a stream of characters on a computer screen while listening to a voice chant a series of letters and numbers. Cues instructed the subjects to switch their attention between vision and hearing. Using magnetic resonance imaging, Shomstein and Yantis found that certain brain regions were activated when the subjects consciously chose to see; these were muted when they chose to hear.

Although music from the car radio or a conversation with a passenger may also compete for a driver's attention, listening is far more passive. "You don't have to put resources into it," Shomstein explains. "And a person sitting with you is aware of the situation as well as you are." The individual in your earphone cannot see the toll plaza ahead. —*Kaspar Mossman*

Political Bias Proved

When people read or hear news about abortion, George W. Bush or Democrats, do they evaluate it fairly before reaching a conclusion? Not at all, say two political scientists at Stony Brook University. Milton Lodge and Charles Taber maintain that people react automatically to "hot button" terms. "Our experiments reveal that they react so quickly—in less than 300 milliseconds—that they cannot be consciously [evaluating] the information," Taber says.

In tests of Stony Brook undergraduates, Lodge and Taber displayed a "prime" word—the name of a politician, such as "Bush" or "Gore," or an issue, such as "death penalty" or "affirmative action"—for 200 milliseconds, long enough to register in perception centers of the brain but not long enough to reach conscious awareness. Then, after flashing a brief blank screen, the researchers presented a "target" word such as "delightful" or "miserable" that stayed on the screen and asked the students to press a "+" key if the target word was associated with a positive emotion or "–" for a negative one. The outcome showed that students' reactions to the nonpolitical target words were affected by their political orientation.


Al Gore


George W. Bush

For example, when Republicans saw "Bush" and then a word such as "joy," they pressed the + key in about 800 milliseconds, but Democrats took around 1,000 milliseconds to do the same. Being primed by "Bush" created an unconscious but negative affect for Democrats, causing them to take longer to shake their predisposition and respond positively to "joy." Similar outcomes occurred with other political primes and unrelated targets, proving that the students were unconsciously reacting positively or negatively. The experiments show that many people get locked into preconceived views that bias them when they process new data.

Can people rid themselves of bias? Yes, Taber conjectures, "but only after getting many pieces of new information and consciously thinking about the issue."

—*Jonathan Beard*

BEN WELSH *age fotostock (top)*; REUTERS/CORBIS (*bottom*)

Upsetting Psychotherapy

Pressure from insurance companies and competition from drug therapies are prompting analysts to get patients off the couch more quickly BY JAMIE TALAN

WENDY SPENT FIVE YEARS in psychoanalysis, delving so deeply into her mind that she could no longer see the connection between her adult problems and her teenage episodes of "cutting" her wrists. After she and her analyst had their final session, during which he welcomed her to move on with her life, Wendy was not completely happy, but she was happier than she ever had been. And that, psychologists say, is successful therapy.

Psychotherapists chafe at rushing patients, but insurers argue that "short-term" therapy is enough.

ANTHONY MARSLAND *Getty Images (doctor and patient)*; GETTY IMAGES *(clock)*

Psychoanalysis probes the unconscious mind to unlock the mysteries that drive conscious emotions and behavior. The discipline is built on pillars set by Sigmund Freud a century ago. It is characterized by frequent sessions that can take place over many years, wherein patients are encouraged to freely associate whatever comes to mind as the analyst sits quietly and listens.

Today the practice is changing. The transformation is in part the result of a better understanding of what works during self-analysis. But increasingly, psychotherapy is changing just to survive, held hostage to limits on insurance coverage determined by managed care companies and facing replacement by psychoactive drugs that in the long run are far cheaper than a patient's weekly visit to the therapist's office. In this incarnation, it suddenly matters less that symptoms may disappear without patients figuring out the underlying cause.

Harsh Reality

To keep psychoanalysis alive, contemporary therapists are revamping Freud's theories. They have discarded some traditional beliefs and have loosened requirements so patients can succeed in fewer sessions. Many analysts are even talking to their patients and sharing their own thoughts and feelings, a practice that Freud said would complicate the treatment process.

Some experts chafe at the changes, however. They say that short-term therapy can be successful for some problems such as phobias but does not work for personality disorders, chronic depression and other substantial mental illnesses. They claim that managed care companies make decisions based on cost, not on any science that shows what works best for a specific condi-

tion. Insurance companies argue that patients can do just as well on medication as they can with talk therapy and that for talk, "short term" is enough.

Extended analysis certainly is under siege. Today patients having long-term psychotherapy—more than 20 sessions—account for only 15 percent of those who seek treatment, according to a study in the *American Journal of Psychiatry*. Psychoanalysts contend that it takes longer to work out issues that have been shaped by a lifetime of emotion and experience, yet they know they must compete in a magic-pill era in which people may be content to have their symptoms disappear without much thought to why they emerged in the first place.

"A better understanding of the self is needed for a better recovery," asserts Gail Saltz, a Manhattan analyst and author of *Becoming Real* (Riverhead Trade, 2005), a book about the benefits of analysis. She says that there are still people who lie on the couch four times a week, but many analysts have accepted a once-a-week regimen. And although studies have shown that certain patients progress better when therapy is frequent, Saltz believes once a week can still be successful. Psychologists have at least agreed that even long-term analysis should be completed within four years.

Regardless of frequency, Saltz says, the goal is to help patients "better tolerate the ups and downs of life" or, as Freud put it, "get beyond everyday human misery." Freud developed his ideas before scientists knew much about the brain's workings, however, and today some of his once popular theories about human development are seen as simply wrong.

High on the list is that infants have complicated sexual desires. Peter D. Kramer, a Massachusetts psychiatrist who popularized the new generation of antidepressants in his best-selling book *Listening to Prozac* (Penguin, 1993), says that "there is no evidence that infants have sexual desires." Kramer notes that although Freud believed that adult complaints of childhood sexual abuse stemmed from such childhood fantasies, the evidence today is plain that sexual abuse of children is common, affecting up to 20 percent of girls and 10 percent of boys.

Freud also had little to offer the therapist in understanding trauma, which experts now know can cause lifelong problems. Trauma therapy is a relatively new field, built on work with war veterans. Post-traumatic stress disorder is a hot topic in psychotherapy today, one that was poorly addressed before, Kramer notes, because it was not possible to have effective treatment when the theoretical underpinnings were shaky.

Patients may be content to have **symptoms disappear** without much thought to why they ever emerged.

Friend, Not Father

Readdressing the basic tenets of psychoanalysis has led to perhaps the most radical change of all: modern psychologists are actually talking to their patients. Freud's original "transference" theory demanded that an analyst remain quiet and aloof so as to serve as a "screen" onto which the patient could project her emotions. But therapists are now sharing more of themselves. "How can I remain opaque when my clients can go online and learn that I love Greek music?" asks psychoanalyst Spyros D. Orfanos, clinic director in psychoanalysis at New York University.

Orfanos says that today's analyst is not an authoritative father figure but a partner in figuring out "the powerful emotional forces that drive behavior." He thinks that having a dialogue with a patient is the best way to work toward change. Many analysts also now agree that empathy is key to the relationship, and empathy requires engagement, not just listening.

Psychoanalysis is also changing in the face of steady competition from other forms of help, such as cognitive behavioral therapy, in which patients try to change certain troubling behaviors, and goal-oriented therapy, which lays out ways to attain, say, certain kinds of relationships. These practices may or may not touch on the patient's past. And to hold its own, psychoanalysis is shedding its image as a privileged treatment for the wealthy; so-called training centers are popping up everywhere that provide low-cost appointments.

Scientists are also attempting to study the biology of the analysis process itself. At New York–Presbyterian Hospital/Weill Cornell Medical Center, psychiatrists Otto F. Kernberg and David A. Silbersweig are recording brain scans of patients before and after analysis. Such studies may help end the debate over the effectiveness of lengthy treatment, notes Kramer, who recently published *Against Depression* (Viking Adult, 2005), an assessment of mood disorders. "We don't know what works or what doesn't work."

Orfanos is dubious about scanning, maintaining that analysis is a humanistic endeavor that does not necessarily fit into a biology-based medical model. "It's about understanding how your mind works," he says, "so that you can have more choices in your life." M

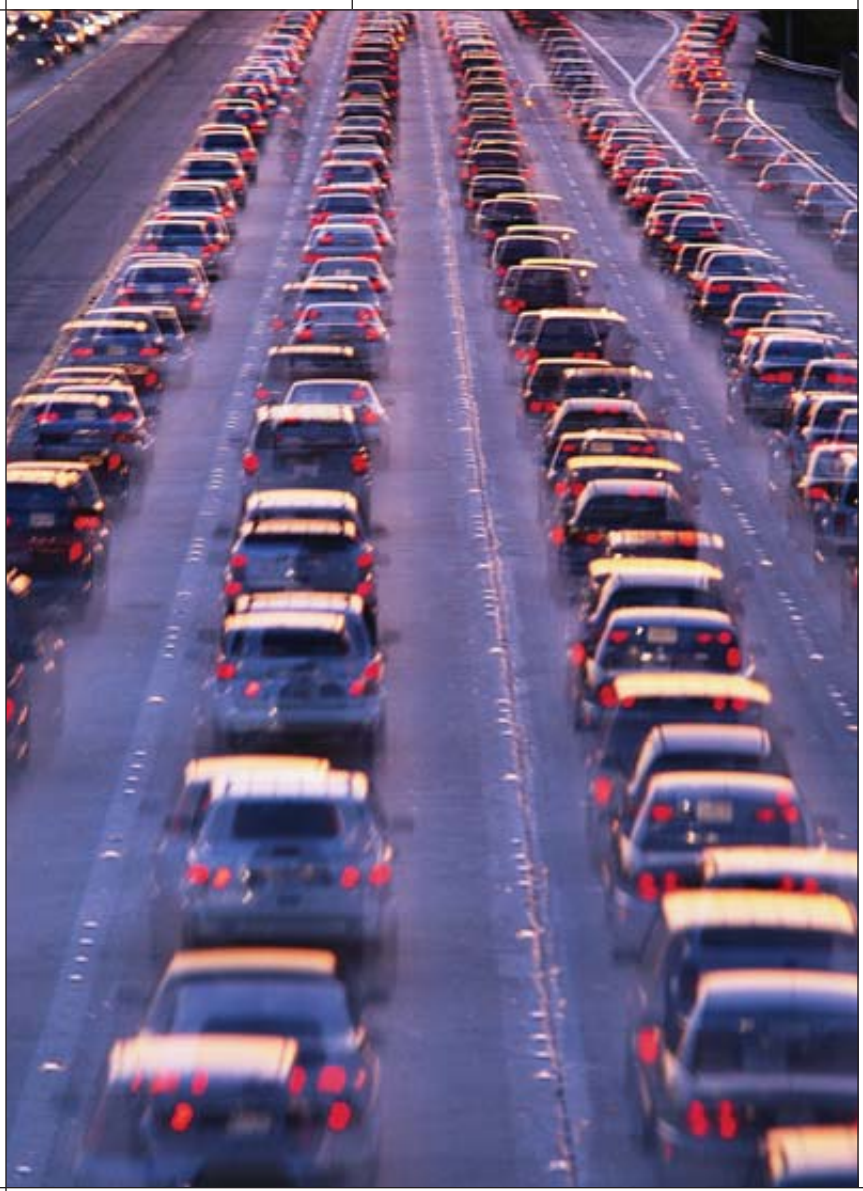
JAMIE TALAN, a science writer at *Newsday*, addressed the ethics of brain scans in the previous issue of *Scientific American Mind*.

Commuting Takes Its Toll

Workers are traveling ever longer to attain the job or home life they want, but the daily stress may outweigh the gains BY ANNETTE SCHAEFER

WHEN ACCIDENTS snarl traffic and bad weather cripples mass transit, images of frustrated commuters often lead the nightly news. But the normal, everyday insanity that commuters endure is the bigger story.

Mobility is a prime mover in today's job markets. Workers who want to "make it" have to be flexible and willing to take the punishment. Move to another branch office? No problem. Still want that nice house in the country? Absolutely. The result of our desires is that more and more people commute, and more travel longer than ever. The percentage of Americans with a commute greater than 90 minutes a day nearly doubled between 1990 and 2000, according to the U.S. Census Bureau.



CORBIS

The added time and distance may not be worth the hassle, however. Research from around the world is leading psychologists to conclude that the heightened stress that commuting puts on individuals and their families can easily overshadow the work and home gains they might realize.

Cost per Minute

Commuting exacts considerable stress on the human mind and body and on family relationships. All the stressors, day in and day out, take their toll. Each added travel minute correlates with an increase in health problems. Several studies have shown that long-distance commuters suffer from psychosomatic disorders at a much higher rate than people with short trips to work. Physical symptoms range from headaches and backaches to digestive problems and high blood pressure. Mental ills include sleep disturbances, fatigue and concentration problems. Commuters who drive have it especially hard—bad weather, traffic jams and accidents all cause stress.

These basic patterns were laid out a decade ago, but since then, American, British, Irish and German studies have advanced our understanding. A 2001 study by scientists at the Center for Psychotherapy Research in Stuttgart and the University Clinic of Ulm in Germany demonstrates just how dramatic the insults can be. The researchers surveyed 407 commuters at the Stuttgart and Ulm railroad stations. The commuters also completed questionnaires covering quality of life and possible psychological problems.

About 90 percent of the men and women had trips of more than 45 minutes each way, putting them in the long-distance category

for many parts of the world. A fair number were extreme commuters, too, trekking as much as three hours daily. Half had been taking the same route for more than five years. "The psychosomatic condition of these people was terrible," says Steffen Haefner, who led the study. The proportion who complained of symptoms such as pain, dizziness, exhaustion and severe sleep deprivation was twice as high as in a control group of noncommuters. Of the long-distance travelers, Haefner says, "31 percent of the men and 37 percent of the women were, from a medical point of view, clearly in need of treatment." Other studies show that workers who use mass transit suffer from higher infection rates and that car drivers have a greater incidence of joint disease.

More neglected, perhaps, are family, friends and hobbies. A 2001 study by Norbert Schneider, a sociology professor at the University of Mainz in Germany, reported in depth on 65 long-distance commuters and the spouses or domestic partners of 45. Almost 60 percent of the workers complained that they had no time to pursue their own interests—no sports, no clubs, not even an occasional outing with friends.

Furthermore, when the people with families finally got home they often had insufficient time for spouses and children. Spending open-ended time playing with the kids or cultivating a shared hobby with a spouse could happen only on weekends or vacations. Interestingly, two thirds of the spouses and partners felt that they were just as burdened—or even more so—noting that they essentially had to take care of all family duties and household chores themselves. Often they managed this task only by sharply curtailing their own professional obligations and personal interests. Perhaps Schneider's deeper finding was that one third of the spouses and partners felt the negatives of a long commute simply were not worth the positives.

So why do individuals subject themselves and their families to this torture? There are three main reasons: a more interesting or better-paying job, the ability to own a home or live in a desirable area, and family priorities such as a better school or proximity to a partner's workplace.

Unfortunately, say Bruno S. Frey and Alois Stutzer of the University of Zurich's Institute for Empirical Research in Economics, the benefits people expect are often unrealized or outweighed by the downsides. The two economists drew that conclusion from their study of several thousand German households that were surveyed annually from 1985 to 1998.

Frey and Stutzer calculated total personal satisfaction values for each individual by tabbing up the "profits" against the "debits" of the disadvantages. They concluded that for every minute longer a worker spends getting to work he will be less satisfied with his life. In a 2004 report the two researchers calculated that Germans who commuted two hours a day were so much more dissatisfied than those with the average commute of 40 minutes that it would take a 40 percent raise in pay to make up for the disgruntledness.

Why Do It?

Experts such as Frey and Stutzer say many workers who commit to a longer commute probably underestimate the human costs. And once the routine is under way, people quickly become accustomed to the greater income or the pretty house in the suburbs. It takes longer for the unpleasant aspects of the grind to set in, yet the physical and mental health effects become stronger and stronger over time.

The degree of dissatisfaction may vary among commuters, however. Schneider found that workers who freely chose to make long trips were better off than those who felt forced into doing so, say, to resolve unemployment.

Other individuals misjudge the strength of their self-determination, according to Haefner. When they first begin commuting, they think, "I'll put up with this for two or three years, and then I'll reconsider things." But the force of habit, chronic shortage of time and lack of energy all thwart the victims from seeking a better solution later. Schneider adds that "long-distance commuters often simply cannot imagine any alternative to the status quo. They do not even think of changing jobs or moving, no matter how much they suffer from the daily ordeal."

Choosing a job closer to home or moving home closer to work are the obvious solutions. If that is not possible, workers can at least explore ways to reduce the human cost of commuting. Carpooling can lighten long drives. Buses or trains can be less taxing if a single, longer route is taken rather than a shorter one that involves transfers, which raises the risk of anxiety-inducing delays and missed connections. People who can sleep for a few minutes on a train often endure commuting life more easily. For nonsleepers, a good book can help; Haefner discovered that train riders who read suffer less than others who fret or do nothing to pass the time. Drivers, of course, should opt for audio books instead. M

Physical symptoms range from headaches to high blood pressure. Mental ills include **sleep disturbances** and poor concentration.

ANNETTE SCHAEFER has a Ph.D. in economics and is a freelance journalist in Hannover, Germany.

HEARING COLORS, TASTING SHAPES

PEOPLE WITH SYNESTHESIA—WHOSE SENSES BLEND TOGETHER—ARE PROVIDING VALUABLE CLUES TO UNDERSTANDING THE ORGANIZATION AND FUNCTIONS OF THE BRAIN

BY VILAYANUR S. RAMACHANDRAN AND EDWARD M. HUBBARD

When Matthew Blakeslee shapes hamburger patties with his hands, he experiences a vivid bitter taste in his mouth. Esmerelda Jones (a pseudonym) sees blue when she listens to the note C sharp played on the piano; other notes evoke different hues—so much so that the piano keys are actually color-coded. And when Jeff Coleman looks at printed black numbers, he sees them in color, each a different hue. Blakeslee, Jones and Coleman are among a handful of otherwise normal people who have synesthesia. They experience the ordinary world in extraordinary ways and seem to inhabit a mysterious no-man's-land between fantasy and reality. For them the senses—touch, taste, hearing, vision and smell—get mixed up instead of remaining separate.

Modern scientists have known about synesthesia since 1880, when Francis Galton, a cousin of Charles Darwin, published a paper in *Nature* on the phenomenon. But most have brushed it aside as fakery, an artifact of drug use or a mere curiosity. About six years ago, however, we and others began to uncover brain processes that could account for synesthesia. Along the way, we also found new clues to some of the most mysterious aspects of the human mind, such as the emergence of abstract thought and metaphor.

DAVID EMMITE

Confirmation that synesthesia is real brings up the question, Why do some people experience it?

A common explanation of synesthesia is that the affected people are simply experiencing childhood memories and associations. Maybe a person had played with refrigerator magnets as a child, and the number 5 was red and 6 was green. This theory does not answer why only some people retain such vivid sensory memories, however. You might *think* of cold when you look at a picture of an ice cube, but you probably do not feel cold, no matter how many encounters you may have had with ice and snow during your youth.

Another prevalent idea is that synesthetes are merely being metaphorical when they describe the note C sharp as "red" or say that chicken tastes "pointy"—just as you and I might speak of a "loud" shirt or "sharp" cheddar cheese. Our ordinary language is replete with such sense-related metaphors, and perhaps synesthetes are just especially gifted in this regard.

We began trying to find out whether synesthesia is a genuine sensory experience in 1999. This deceptively simple question had plagued researchers in the field for decades. One natural approach is to start by asking the subjects outright: "Is this just a memory, or do you actually see the color as if it were right in front of you?" When we asked this question, we did not get very far. Some subjects did respond, "Oh, I see it perfectly clearly." But a more frequent reaction was, "I kind of see it, kind of don't" or "No, it is not like a memory. I see the number as being clearly red, but I also *know* it isn't; it's black. So it must be a memory, I guess."

FAST FACTS

Synesthesia

1» Synesthesia (from the Greek roots *syn,* meaning "together," and *aisthesis,* or "perception") is a condition in which people experience the blending of two or more senses.

2» Perhaps it occurs because of cross activation, in which two normally separate areas of the brain elicit activity in each other.

3» As scientists explore the mechanisms involved in synesthesia, they are also learning about how the brain in general processes sensory information and uses it to make abstract connections between seemingly unrelated inputs.

To determine whether an effect is truly perceptual, psychologists often use a simple test called pop-out or segregation. If you look at a set of tilted lines scattered amid a forest of vertical lines, the tilted lines stand out. Indeed, you can instantly segregate them from the background and group them mentally to form, for example, a separate triangular shape. Similarly, if most of a background's elements were green dots and you were told to look for red targets, the red ones would pop out. On the other hand, a set of black 2's scattered among 5's of the same color almost blend in [*see box on page 21*]. It is hard to discern the 2's without engaging in an item-by-item inspection of numbers, even though any individual number is just as clearly different from its neighbors as a tilted line is from a straight line. We thus may conclude that only certain primitive, or elementary, features, such as color and line orientation, can provide a basis for grouping. More complex perceptual tokens, such as numbers, cannot.

We wondered what would happen if we showed the mixed numbers to synesthetes who experience, for instance, red when they see a 5 and green with a 2. We arranged the 2's so that they formed a triangle.

When we conducted pop-out tests with volunteers, the answer was crystal clear. Unlike normal subjects, synesthetes correctly reported the shape formed by groups of numbers up to 90 percent of the time (exactly as nonsynesthetes do when the numbers actually have different colors). This result proves that the induced colors are genuinely sensory and that synesthetes are not just making things up. It is impossible for them to fake their success.

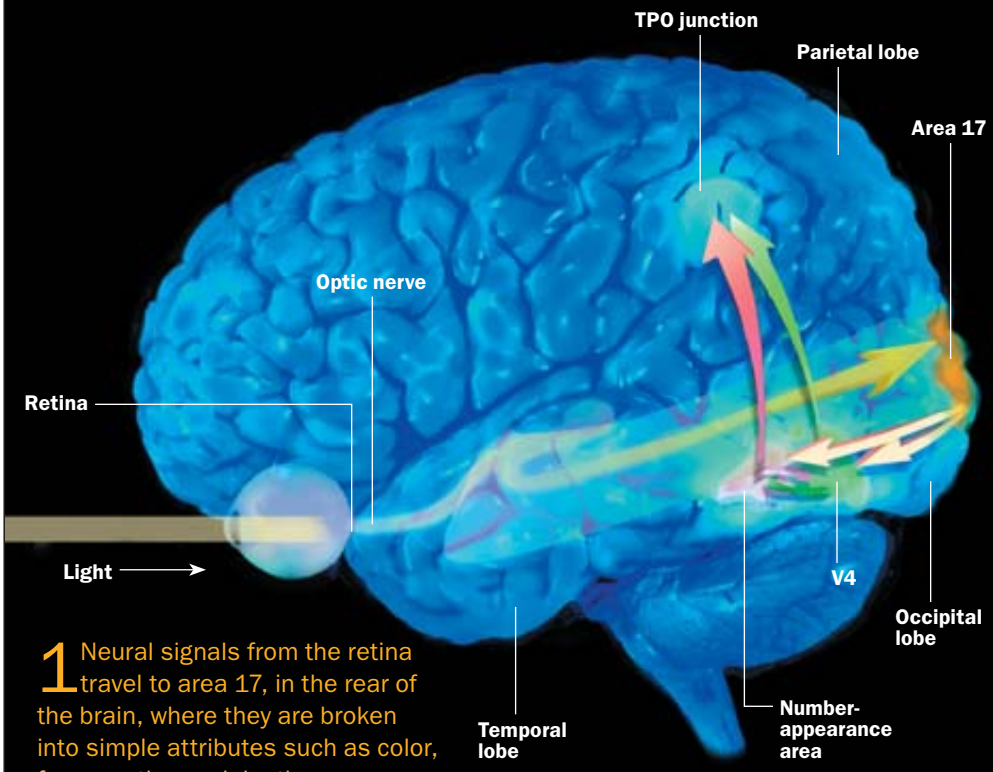
Visual Processing

Confirmation that synesthesia is real brings up the question, Why do some people experience this weird phenomenon? Our experiments lead us to favor the idea that synesthetes are experiencing the result of some kind of cross wiring in the brain. This basic concept was initially proposed about 100 years ago, but we have now identified where and how such cross wiring might occur.

An understanding of the neurobiological factors at work requires some familiarity with how the brain processes visual information. After light

Mixed Signals

In one of the most common forms of synesthesia, looking at a number evokes a specific hue. Brain areas that normally do not interact when processing numbers or colors do activate one another in synesthetes.



1 Neural signals from the retina travel to area 17, in the rear of the brain, where they are broken into simple attributes such as color, form, motion and depth

2 Color information continues on to V4, near where the visual appearance of numbers is also represented—and thus is a site for cross-linking between the color and number areas (*pink* and *green arrows*)

3 Ultimately, color proceeds "higher," to an area near the TPO (for *t*emporal, *p*arietal, *o*ccipital lobes) junction, which may perform more sophisticated color processing

CAROL DONNER

reflected from a scene hits the cones (color receptors) in the eye, neural signals from the retina travel to area 17, in the occipital lobe at the back of the brain. There the image is processed further within local clusters, or blobs, into such simple attributes as color, motion, form and depth. Afterward, information about these separate features is sent forward and distributed to several far-flung regions in the temporal and parietal lobes. In the case of color, the information goes to area V4 in the fusiform gyrus of the temporal lobe. From there it travels to areas that lie farther up in the hierarchy of color centers, including a region near a patch of cortex called the TPO (for the junction of the *t*emporal, *p*arietal and *o*ccipital lobes). These higher areas may be concerned with more sophisticated aspects of color processing. For example, leaves look as green at dusk as they do at midday, even though the mix of wavelengths reflected from them is very different.

Numerical computation, too, seems to happen in stages. An early step also takes place in the fusiform gyrus, where the actual shapes of numbers are represented, and a later one occurs in the angular gyrus, a part of the TPO that is concerned with numerical concepts such as ordinality (sequence) and cardinality (quantity). (When the angular gyrus is damaged by a stroke or a tumor, the patient can still identify numbers but can no longer divide or subtract. Multiplication often survives because it is learned by rote.) In addition, brain-imaging studies in humans strongly hint that visually presented letters of the alphabet or numbers (graphemes) activate cells in the fusiform gyrus, whereas the sounds of the syllables (phonemes) are processed higher up, once again in the general vicinity of the TPO.

Because both colors and numbers are processed initially in the fusiform gyrus and subsequently near the angular gyrus, we suspected that number-color synesthesia might be caused by cross wiring between V4 and the number-appearance area (both within the fusiform) or between the higher color area and the number-concept area (both in the TPO). Other, more exotic forms of the condition might result from similar

cross wiring of different sensory-processing regions. That the hearing center in the temporal lobes is also close to the higher brain area that receives color signals from V4 could explain sound-color synesthesia. Similarly, Matthew Blakeslee's tasting of touch might occur because of cross wiring between the taste cortex in a region called the insula and an adjacent cortex representing touch by the hands.

Assuming that neural cross wiring does lie at the root of synesthesia, why does it happen? We know that synesthesia runs in families, so it has a genetic component. Perhaps a mutation causes connections to emerge between brain areas that are usually segregated. Or maybe the mutation leads to defective pruning of preexisting connections between areas that are normally connected only sparsely. If the mutation were to be expressed (that is, to exert its effects) in some brain areas but not others, this patchiness might explain why some synesthetes conflate colors and numbers, whereas others see colors when they hear phonemes or musical notes. People who have one type of synesthesia are more likely to have another, which adds weight to this idea.

Although we initially thought in terms of physical cross wiring, we have come to realize that the same effect could occur if the wiring—the number of connections between regions—was fine but the balance of chemicals traveling between regions was skewed. So we now speak in terms of cross activation. For instance, neighboring brain regions often inhibit one another's activity, which serves to minimize cross talk. A chemical imbalance of some kind that reduces such inhibition—for example, by blocking the action of an inhibitory neurotransmitter or failing to produce an inhibitor—would also cause activity in one area to elicit activity in a neighbor. Such cross activation could, in theory, also occur between widely separated areas, which would account for some of the less common forms of synesthesia.

Support for cross activation comes from other experiments, some of which also help to explain the varied forms synesthesia can take. One takes advantage of a visual phenomenon known as crowding [*see box on opposite page*]. If you stare at a small plus sign in an image that also has a number 5 off to one side, you will find that it is easy to discern that number, even though you are not looking at it directly. But if we now surround the 5 with four other numbers, such as 3's, then you can no longer identify it. It looks out of focus. Volunteers who perceive normally are no more successful at identifying this number than mere chance. That is not because things get fuzzy in the periphery of vision. After all, you could see the 5 perfectly clearly when it was not surrounded by 3's. You cannot identify it now because of limited attentional resources. The flanking 3's somehow distract your attention away from the central 5 and prevent you from seeing it.

A big surprise came when we gave the same test to two synesthetes. They looked at the display and made remarks like, "I cannot see the middle number. It's fuzzy, but it looks red, so I guess it must be a 5." Even though the middle number did not consciously register, it seems that the brain was nonetheless processing it somewhere. Synesthetes could then use this color to deduce intellectually what the number was. If our theory is right, this finding implies that the number is processed in the fusiform gyrus and evokes the appropriate color *before* the stage at which the crowding effect occurs in the brain; paradoxically, the result is that even an "invisible" number can produce synesthesia.

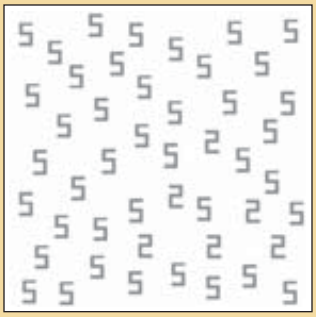
Another finding we made also supports this conclusion. When we reduced the contrast between the number and the background, the synesthetic color became weaker until, at low contrast, subjects saw no color at all, even though the number was perfectly visible. Whereas the crowding experiment shows that an invisible number can elicit color, the contrast experiment conversely indicates that viewing a number does not guarantee seeing a color. Perhaps low-contrast numbers activate cells in the fusiform adequately for conscious perception of the number but not enough to cross-activate the color cells in V4.

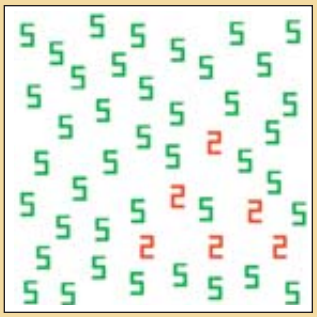
Finally, we found that if we showed synesthetes Roman numerals, a V, say, they saw no color—which suggests that it is not the numerical *concept* of a number, in this case 5, but the grapheme's visual appearance that drives the color. This observation, too, implicates cross ac-

Synesthesia is much more common in creative people than in the general population.

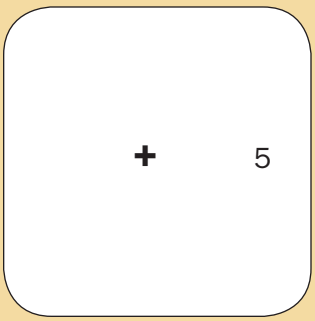
Color-Coded World

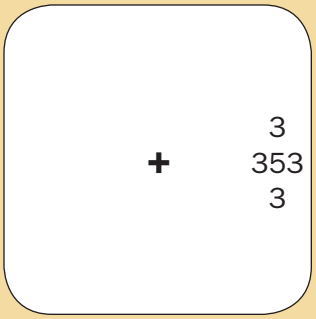
In a test of visual-segregation capabilities, synesthetes who link a specific hue with a given number can instantly see an embedded pattern in an image with black numbers scattered on a white page. Whereas a person with normal perception must undertake a digit-by-digit search to pick out, in this example, 2's amid 5's (*left*), the triangle-shaped group of 2's pops out for an individual with synesthesia (*right*).





"Invisible" numbers show up for synesthetes in a perceptual test. When a person stares at a central object, here a plus sign, a single digit off to one side is easy to see with peripheral vision (*left*). But if the number is surrounded by others (*right*), it appears blurry—invisible—to the average person. In contrast, a synesthete could deduce the central number by the color it evokes.





tivation within the fusiform gyrus itself in number-color synesthesia, because that structure is mainly involved in analyzing the visual shape, not the high-level meaning, of the number. One intriguing twist: Imagine an image with a large 5 made up of little 3's; you can see either the "forest" (the 5) or focus minutely on the "trees" (the 3's). Two synesthete subjects reported that they saw the color switch, depending on their focus. This test implies that even though synesthesia can arise as a result of the visual appearance alone—not the high-level concept—the manner in which the visual input is categorized, based on attention, is also critical.

But as we began to recruit other volunteers, it soon became obvious that not all synesthetes who colorize their world are alike. In some, even days of the week or months of the year elicit colors.

The only thing that days of the week, months and numbers have in common is the concept of numerical sequence, or ordinality. For certain synesthetes, perhaps it is the abstract concept of numerical sequence that drives the color, rather than the visual appearance of the number. Could it be that in these individuals, the cross wiring occurs between the angular gyrus and the higher color area near the TPO instead of between areas in the fusiform? If so, that interaction would explain why even abstract number representations, or the *idea* of the numbers elicited by days of the week or months, will strongly evoke specific colors. In other words, depending on where in the brain the synesthesia gene is expressed, it can result in different types of the condition—"higher" synesthesia, driven by numerical concept, or "lower" synesthesia, produced by visual appearance alone. Similarly, in some lower forms, the visual appearance of a letter might generate color, whereas in higher forms it is the *sound,* or phoneme, summoned by that letter; phonemes are represented near the TPO.

We also observed one case in which we believe cross activation enables a colorblind synesthete to see numbers tinged with hues he otherwise cannot perceive; charmingly, he refers to these as "Martian colors." Although his retinal color receptors cannot process certain wave-

(The Authors)

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Common Questions

Are there different types of synesthesia?
Science counts about 50. The condition runs in families and may be more common in women and creative people; perhaps one person in 200 has synesthesia. In the most prevalent type, looking at numbers or listening to tones evokes a color. In one rare kind, each letter is associated with the male or female sex—an example of the brain's tendency to split the world into binary categories.

If a synesthete associates a color with a single letter or number, what happens if he looks at a pair of letters, such as "ea," or double digits, as in "25"?
He sees colors that correspond with the individual letters and numbers. If the letters or numbers are too close physically, however, they may cancel each other out (color disappears) or, if the two happen to elicit the same color, enhance each other.

Does it matter whether letters are uppercase or lowercase?
In general, no. But people have sometimes described seeing less saturated color in lowercase letters, or the lowercase letters may appear shiny or even patchy.

How do entire words look?
Often the color of the first letter spreads across the word; even silent letters, such as the "p" in "psalm," cause this effect.

What if the synesthete is multilingual?
One language can have colored graphemes, but a second (or additional others) may not, perhaps because separate tongues are represented in different brain regions.

What about when the person mentally pictures a letter or number?
Imagining can evoke a stronger color than looking at a real one. Perhaps that exercise activates the same brain areas as does viewing real colors—but because no competing signals from a real number are coming from the retina, the imagined one creates a stronger synesthetic color.

Does synesthesia improve memory?
It can. The late Russian neurologist Aleksandr R. Luria described a mnemonist who had remarkable recall because all five of his senses were linked. Even having two linked senses may help.

—V.S.R. and E.M.H.

lengths, we suggest that his brain color area is working just fine and being cross-activated when he sees numbers.

In brain-imaging experiments we conducted with Geoffrey M. Boynton of the Salk Institute for Biological Studies in San Diego, we have obtained preliminary evidence of local activation of the color area V4 in a manner predicted by our cross-activation theory of synesthesia. (The late Jeffrey A. Gray of the Institute of Psychiatry in London and his colleagues reported similar results.) On presenting black and white numbers to synesthetes, brain activation arose not only in the number area—as it would in normal subjects—but also in the color area. Our group also observed differences between types of synesthetes. Subjects with lower synesthesia showed much greater activation in earlier stages of color processing than did control subjects. In contrast, higher synesthetes show less activation at these earlier levels.

A Way with Metaphor

Our insights into the neurological basis of synesthesia could help explain some of the creativity of painters, poets and novelists. According to one study, the condition is much more common in creative people than in the general population.

One skill that many creative people share is a facility for using metaphor ("It is the east, and Juliet is the sun"). It is as if their brains are set up to make links between seemingly unrelated domains—such as the sun and a beautiful young woman. In other words, just as synesthesia involves making arbitrary links between seemingly unrelated perceptual entities such as colors and numbers, metaphor involves making links between seemingly unrelated conceptual realms. Perhaps this is not just a coincidence.

Numerous high-level concepts are probably anchored in specific brain regions, or maps. If you think about it, there is nothing more abstract than a number, and yet it is represented, as we have seen, in a relatively small brain region, the angular gyrus. Let us say that the mutation we believe brings about synesthesia causes excess communication among different brain maps—small patches of cortex that represent specific perceptual entities, such as sharpness or curviness of shapes or, in the case of color maps, hues. Depending on where and how widely in the brain the trait was expressed, it could lead to both synesthesia and a propensity toward linking seemingly unrelated concepts and ideas—in short, creativity. This would explain why the apparently useless synesthesia gene has survived in the population.

In addition to clarifying why artists might be prone to experiencing synesthesia, our research suggests that we all have some capacity for it and that this trait may have set the stage for the evolution of abstraction—an ability at which humans excel. The TPO (and the angular gyrus within it), which plays a part in the condition, is normally

One man with synesthesia knew his chicken was ready when it tasted "pointy."

involved in cross-modal synthesis. It is the brain region where information from touch, hearing and vision is thought to flow together to enable the construction of high-level perceptions. For example, a cat is fluffy (touch), it meows and purrs (hearing), it has a certain appearance (vision) and odor (smell), all of which are derived simultaneously by the memory of a cat or the sound of the word "cat."

Could it be that the angular gyrus—which is disproportionately larger in humans than in apes and monkeys—evolved originally for cross-modal associations but then became co-opted for other, more abstract functions such as metaphors? Consider two drawings, originally designed by psychologist Wolfgang Köhler. One looks like an inkblot and the other, a jagged piece of shattered glass. When we ask, "Which of these is a 'bouba,' and which is a 'kiki'?" 98 percent of people pick the inkblot as a bouba and the other as a kiki. Perhaps that is because the gentle curves of the amoebalike figure metaphorically mimic the gentle undulations of the sound "bouba," as represented in the hearing centers in the brain as well as the gradual inflection of the lips as they produce the curved "boo-baa" sound. In contrast, the waveform of the sound "kiki" and the sharp inflection of the tongue on the palate mimic the sudden changes in the jagged visual shape. The only thing these two kiki features have in common is the abstract property of jaggedness that is extracted somewhere in the vicinity of the TPO, probably in the angular gyrus. In a sense, perhaps we are all closet synesthetes.

So the angular gyrus performs a very elementary type of abstraction—extracting the common denominator from a set of strikingly dissimilar entities. We do not know exactly how it does this job. But once the ability to engage in cross-modal abstraction emerged, it might have paved the way for the more complex types of abstraction.

When we began our research on synesthesia, we had no inkling of where it would take us. Little did we suspect that this eerie phenomenon, long regarded as a mere curiosity, might offer a window into the nature of thought. M

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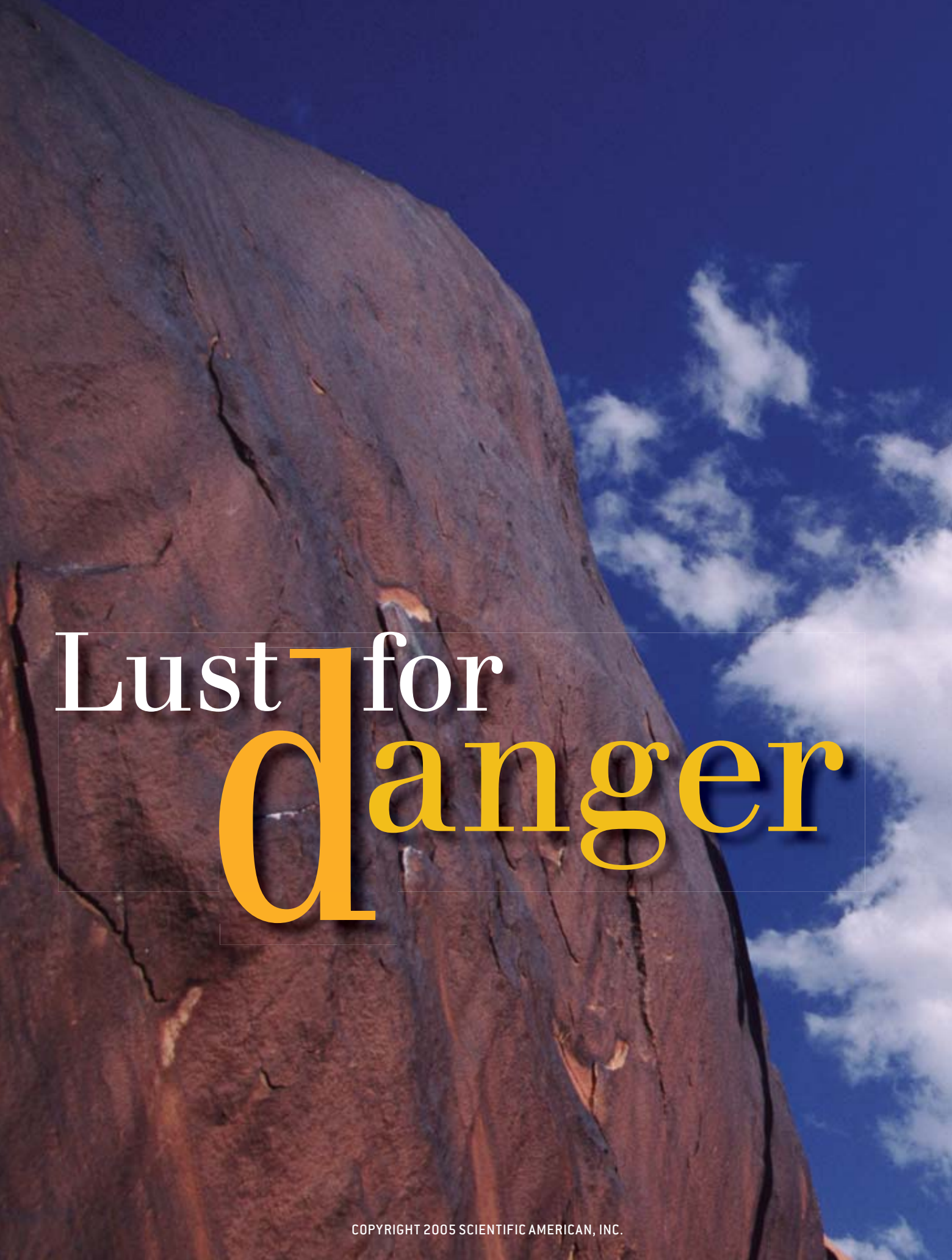
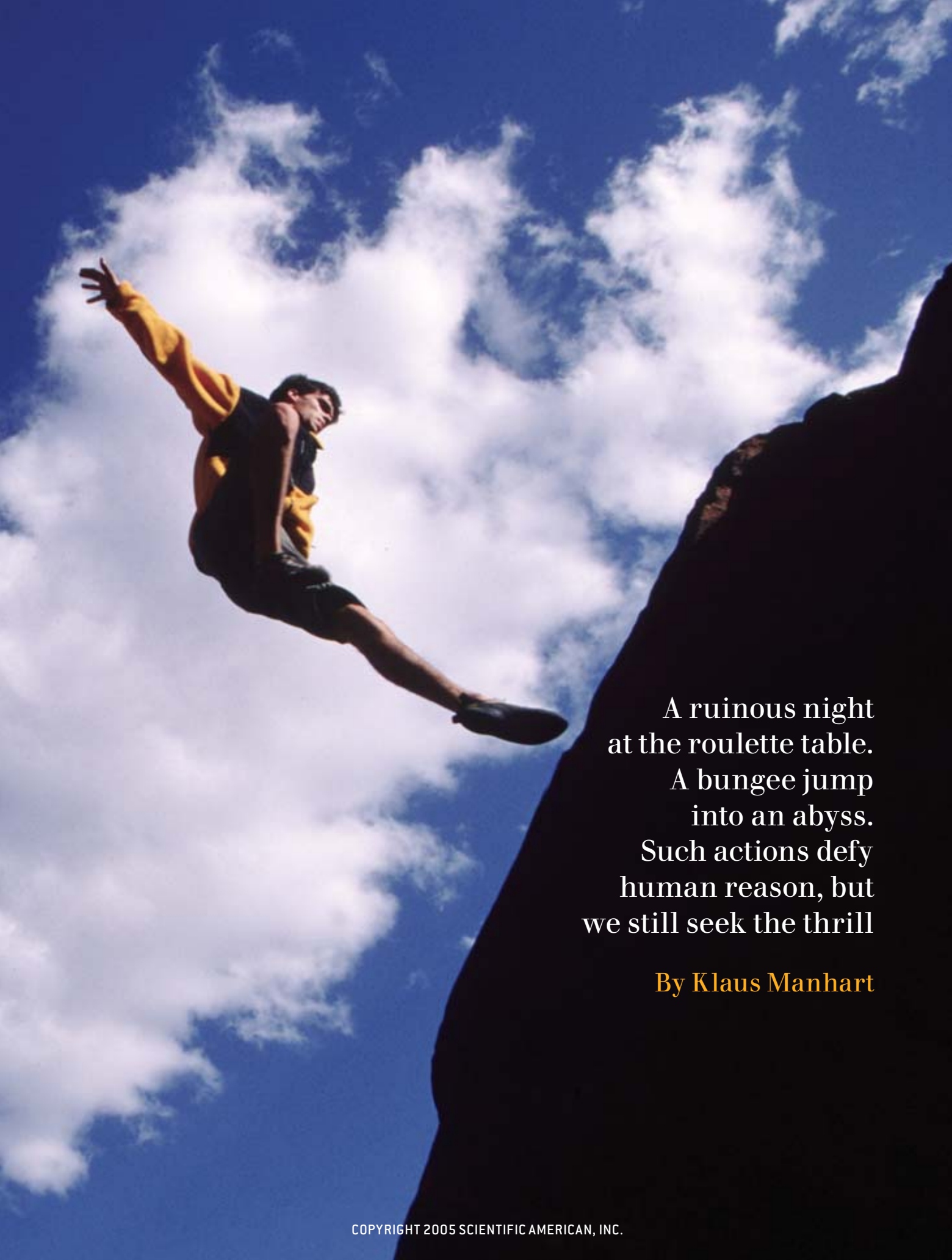


Lust for danger



A ruinous night at the roulette table. A bungee jump into an abyss. Such actions defy human reason, but we still seek the thrill

By Klaus Manhart

The two empty cars sit idling, side by side. Jim and Buzz each get into their vehicles, close the doors and push their gas pedals to the floor, racing headlong toward the edge of a cliff. The canyon below comes into view—they should each leap from their driver's seats before their cars vault into the abyss, but the first one to bail out loses. At the last possible moment Jim throws open his door and dives out onto the ground. Buzz waits too long and plummets over the edge to certain death.

FATAL ACTION
Drivers race in the street, flouting possible arrest or death—taking the risk can give the brain a chemical high.

In *Rebel Without a Cause,* James Dean's character, Jim, symbolizes a turbulent generation of young people in the 1950s who went to extremes to find their own identities. Teenagers pushed risky behavior to the limit, senselessly putting their lives on the line. Yet this desire to court danger crosses every era, age group and social class. Reckless driving, for example, is common on highways around the world. Mountain climbers cling to sheer rock faces, skiers rush down steep slopes, married people have secret affairs, and partygoers drink to excess.

When danger calls, it seems, many are ready to respond. Today men and women of all ages are suddenly playing Texas Hold 'Em in homes, schools, offices and casinos, risking real money just for the thrill of it. In the late 1990s responsible parents who for years had safely put their

ERIC PERLMAN *Corbis (preceding pages);* RICK FRIEDMAN *Corbis (this page)*

Ancestors who roamed took greater risks than cave dwellers but passed down stronger survival skills.

savings into family bank accounts risked everything on grossly speculative high-tech stocks in hopes of cashing in on the dot-com boom. Thrill-seeking behavior is ubiquitous in other cultures, too: in Africa and South America, members of various tribes risk all their worldly possessions on games of chance.

Why do we have such a passion for dangerous situations, even when the outcome can literally be fatal? Because these activities give the brain a chemical high, and we like how it feels. And why would the brain reward us for risky behavior? Because taking chances helped early humans find food and mates, and those successful risk takers passed on their genes to us. Still, we certainly have the reasoning power to deny ourselves dangerous pleasures, yet so frequently we do not, and today psychologists are trying to determine why we can't seem to avoid the trouble we get ourselves into.

Adventurers Rule

The quest to explain why we lust for danger has ebbed and flowed over the years. But as our understanding has progressed, it has become evident that humans are driven to take risks—and the more that they do, the more likely they are to thrive. According to the accepted theory most recently advanced by biologist Jay Phelan of the University of California at Los Angeles and economist Terry Burnham, formerly of Harvard Business School, our penchant stems from prehistoric times, when the world was populated by two basic types of humans: those who nested and those who ventured forth. Nesters pretty much stayed in their caves, subsisting on plants and small animals in their immediate vicinity, remaining ever cautious. Adventurers roamed the land; although their daring exploits put them at greater risk of getting killed, they also discovered the tastier fruits and the more productive hunting grounds. At the same time, they gathered practical survival experience, becoming better equipped to withstand the rigors of nature. These more capable doers were frequently able to live long enough to have numerous children, successfully passing on their genes until their type eventually came to dominate our species.

Our passion for taking risks is therefore a biological legacy, and a preference for such behavior continues to pervade society today. Of course, rational thinking in the 21st century can readily overcome such biological preference. Yet it is difficult to deny that the brain interprets risky behavior as a sign of strength. For example, psychologists have shown that young women, at gut level, are more attracted to "dangerous" men than to "safe" men. One reason is that despite obvious complications, the "outlaw" type may be more likely to come out on top should conflict with others arise. The "tough guy" may appear to offer women greater protection for physical survival.

DEX IMAGES/CORBIS

FALSE HOPE Humans judge probabilities poorly, giving gamblers blind faith they can win despite poor odds.

This association is particularly evident in cultures that have changed little throughout the ages. In the 1960s and 1970s American cultural anthropologist Napoleon A. Chagnon of the University of California at Santa Barbara conducted a study of the Yanomamo Indians, who live along the Brazilian-Venezuelan border. He discovered that certain males lived with many more women than the rest, and every one of these men was known as a fearless warrior. These men also fathered far more offspring than their more timid tribesmen. Chagnon concluded that aggression-oriented genes win the upper hand in human reproduction.

Addicted to Dopamine

In the past decade, studies of brain chemicals and genes have supported Chagnon's supposi-

SELF-DECEIT Office affairs flare up because individuals think they are less likely to be detected than lovers exposed elsewhere.

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People with an excessive need to be energized by dopamine accept danger as part of life's game.

tion. Humans are driven to seek thrills, and for some, the more they find the more they want.

Such drives vary greatly among individuals. For certain people, even the minimum bet during a friendly game of poker can rattle the nerves. Others relish parachuting out of airplanes. The difference may be explained by each person's dopamine system—how much of this neurotransmitter people have and how readily it can transmit messages between neurons. For the biggest thrill seekers, dopamine brings about a very real state of intoxication; the more that is released by a thrill, the greater their rush.

Psychologists refer to such behavior as "sensation seeking," and a mix of physical and psychological factors are at work. People with a greater need to be energized by dopamine generally accept the physical, social or financial risks of sensation seeking as part of the game. But what causes the strong dopamine response? Psychologist Marvin Zuckerman of the University of Delaware maintains that the culprit is monoamine oxidase B. This enzyme is one of the chemicals that breaks down dopamine. The less monoamine oxidase B a person has, the more the dopamine flows, and the more likely he or she is to be a thrill seeker.

Genes may play a part, too. In 1996 scientists discovered a gene called the *D4 dopamine receptor,* quickly dubbed the novelty-seeking gene. It provides the code for a specific dopamine receptor and was thought to be responsible for minimizing the anxiety that normally accompanies risky behavior. People who have this receptor tend to go to excessive measures to get a rush. For these folks, commonplace situations that other people would find stimulating produce little more than boredom. Other experts are not convinced about this gene's power, however. Some 18 studies done since 1996 have examined the link between its occurrence and thrill-seeking behavior, but only half of them have found any quantifiable connection.

Invincible Me

To some psychologists, a person's readiness to give in to the temptation to seek thrills is an extreme case of a more general human trait—the tendency to estimate risk poorly and to overinflate anticipated performance. For example, according to psychological surveys, most people believe themselves to be healthier than the average person. They also feel that they are more astute in judging profit-making schemes. Experts refer to this phenomenon as the "optimistic bias." It occurs when danger is recognized but the level of risk is not accurately perceived. This skewed view would explain why a heavy smoker tends to estimate his cancer risk as less severe

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SMOKE SCREEN Heavy smokers wrongly estimate their cancer susceptibility as lower than that for moderate smokers of the same age.

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SAFE THRILL Society offers secure situations that can satisfy our impulse to feel keenly alive.

GETTY IMAGES

than a moderate smoker of the same age and gender does.

Underestimation also suppresses our fearful emotions. We simply assume that we will not be affected or at least that we are less susceptible to harm than others might be. As a result, we also become less willing to take precautions. Studies by Matthew Kreuter of the Saint Louis University School of Public Health and Victor J. Strecher of the University of Michigan at Ann Arbor indicate that people often indulge in unhealthy or risky behavior despite being fully aware of the danger involved. Examples abound, such as the five skiers near Park City, Utah, this past winter who ignored warning signs and jumped fences to ski down unchecked terrain—to their deaths.

Humans in general are not very good at weighing risks. We are "probability blind." If a roulette wheel stops on red five times in a row, many onlookers will hold the false belief that on the next spin, chances are higher than normal that the wheel will hit black. Of course, every spin has the same mathematical probability of coming up red or black: 50–50. Yet casino gam-

blers by the thousands succumb to such fallacious thinking.

In much the same way, people are scared of plane crashes far more than car accidents, because an airline disaster is more dramatic, even though a much higher percentage of travelers die while riding on the road. We also roundly fear spectacular causes of death, such as murder, being struck by lightning or being bitten by a poisonous snake, even though the chance that we would fall prey to such an exotic demise is very small. Casino owners, lottery ticket sellers and insurance agents shamelessly exploit our miscalculations to sell that "winning" ticket or that "safety" policy against odds that are highly unlikely.

How is it, then, that the human brain, which can comprehend much more complex mathematical relationships, can make such fundamental errors in judgment? Evolution may provide an answer here as well. As the brain developed over millennia, events such as attacks from enemies and bites from snakes posed real dangers that became strongly imprinted in our neural circuitry. Our fears are therefore not completely unfounded, yet they do not really pertain to the modern world.

Still, the brain cannot easily adjust to such abstract probabilities. How many people who buy a lottery ticket are really considering the fact that they must rule out 14 million incorrect numerical combinations in choosing the exact winner? Instead we apply bogus, though seemingly time-tested, rules of thumb. As psychologists Daniel Kahneman of Princeton University and the late Amos Tversky discovered in their research on statistical fallacies, we tend to believe that the more memorable an event, the more often it is likely to occur.

Fake It Instead

In dangerous situations, bad math, underestimation of risk and overestimation of our own strengths conspire to make us lose more than win, yet we willingly wade into them anyway. Mathematicians who study gambling have calculated that in the long term, players always come out on the losing end. Statistically, for example, regular roulette players win about 95 percent of their investment—that is, they lose 5 percent of their money. Sociologists often say that playing such games is the equivalent of paying a "stupidity tax."

In risky situations, our insufficient sense of probability enters into a dangerous liaison with dopamine intoxication. In assessing our chances, we cannot trust our intuitive, primitive brains to make decisions. Rather we must rely on an unemotional analysis of the actual factors that are involved.

Of course, that is easier said than done. For many people, reason simply takes a vacation when the chance for thrills arises. Deliberate precautions may therefore be the best way to counter temptation. One proven strategy recommended by psychologists is self-policing—setting limits before an activity begins. Gamblers, who run the risk of losing their shirts, can bring a predetermined amount of money with them into a casino or tell friends to escort them out, forcibly if needed, at a certain time. Greek hero Odysseus, who wanted to hear the seductive song of the Sirens, cheated death with such a strategy: he ordered his crew to lash him to their ship's mast and to fill their own ears with wax so they would not hear the song that would have tempted them to steer onto the rocks.

A second strategy is to substitute artificial danger for real danger. We do not have to abstain completely from the dopamine high or risk our health or wealth. Modern society offers many safe thrill-seeking situations: the exhilarating ride of a roller coaster, the fright of a horror film, the fast-paced intensity of a video game. These experiences drive up our dopamine levels and make us feel keenly alive. Our brains do not differentiate whether the rush is real or manufactured. We can live on the edge without risking going over it. M

> Video games and horror films allow us to live on the edge without going over it.

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ESSAY

SMARTER on DRUGS

We recoil at the idea of people taking drugs to enhance their intelligence. But why?

By Michael S. Gazzaniga

Any child can tell you that some people are smarter than others. But what is the difference between the brain of a Ph.D. student and the brain of the average Joe? If we can figure that out, then a bigger question follows: Is it ethical to turn average Joes into geniuses? Evolutionary theory suggests that if we are smart enough to invent technology that can increase our brain capacity, we should be able to use that advantage. It is the next step in the survival of the fittest. As noted psychologist Corneliu Giurgea stated in the 1970s, "Man is not going to wait passively for millions of years before evolution offers him a better brain."

That said, gnawing concerns persist when it comes to artificially enhancing intelligence. Geneticists and neuroscientists have made great strides in understanding which genes, brain structures and neurochemicals might be altered artificially to increase intelligence. The fear this prospect brings is that a nation of achievers will discard hard work and turn to prescriptions to get ahead.

Enhancing intelligence is not science fiction. Many "smart" drugs are in clinical trials and could be on the market in less than five years. Some medications currently available to patients with memory disorders may also increase intelligence in the healthy population. Likewise, few people would lament the use of such aids to ameliorate the forgetfulness that aging brings. Drugs that counter these deficits would be adopted gratefully by millions of people.

Drugs designed for psychotherapy can also be used to enhance certain regular mental functions. Just as Ritalin can improve the academic performance of hyperactive children, it can do

JASON HETHERINGTON *Getty Images (opposite page)*; GETTY IMAGES *(above)*

the same for normal children. It is commonly thought to boost SAT scores by more than 100 points, for both the hyperactive and the normal user. Many healthy young people now use it that way for that purpose, and quite frankly, there is no stopping this abuse.

In a way, with these new compounds, we are reliving the stories associated with better-known illegal psychoactive drugs. Morphine is a terrific help with pain produced by burns and other somatic ills; it is also a mind-altering substance that in some areas of society causes tremendous social and psychological problems. Do we stop developing such painkillers just because they might be misused? Even when the issue is simple memory enhancement, we profess great social concern. Why do we resist changes in our cognitive skills through drugs?

The reason, it seems to me, is that we think cognitive enhancement is cheating. If, somehow, someone gets ahead through hard work, that's okay. But popping a pill and mastering information after having read it only once seems unfair.

This position makes no sense. Among the normal population are men and women with incredible memories, fast learners of language and music, and those with enhanced capabilities of all kinds. Something in their brains allows them to encode new information at lightning speed. We accept the fact that they must have some chemical system that is superior to ours or some neural circuitry that is more efficient. So why should we be upset if the same thing can be achieved with a pill? In some way, we were cheated by Mother Nature if we didn't get the superior neural system, so for us to cheat her back through our own inventiveness seems like a smart thing to do. In my opinion, it is exactly what we should do.

Memory Enhancers

Already available, or making their way through the Federal Drug Administration's approval process, are several cognitive enhancers that reportedly improve memory. These are also being called smart drugs, or nootropes, from the Greek *noos,* for "mind," and *tropein,* for "toward." Whenever a study shows that a certain chemical produces even a moderate increase in memory in an animal population (be it fruit flies, mice or humans), one of two things happens. If the compound is not on the market, a pharmaceutical company quickly jumps in to exploit the finding. If the drug is already on the market but is used to treat a known ailment—for instance, Alzheimer's or attention-deficit hyperactivity disorder—a surge takes place in off-label use, for a purpose other than the intended application. Some regulated smart drugs are currently on the market, as are unregulated herbal medications. Entire stores called smart bars have popped up along the West Coast to sell these items.

Work on memory enhancers may be furthest along. Eric R. Kandel of Columbia University, who won a Nobel Prize for his research on learning and memory in the sea slug *Aplysia,* is one proponent. He found that learning occurs at the synapse (the junction between two neurons) by several means. The synapse is enhanced when a protein called CREB is activated, and CREB plays a role in memory formation in fruit flies and in mice. With these discoveries came the 1998 birth of Memory Pharmaceuticals, Kandel's Montvale, N.J.–based company, which hopes to formulate a drug that will raise the amount of CREB in the human neural system and thus facilitate the formation of long-term memories. One of the most promising chemicals is called MEM 1414. If clinical trials go well, MEM 1414 could be on the market after 2008. At least one other company, Helicon Therapeutics in Farmingdale, N.Y., is also investigating CREB to improve human memory formation.

Alternative drugs are also in the works based on other brain mechanisms. Before a neuron naturally increases CREB, certain channels on its membrane must open to allow positive ions to flow into the cell. The ions then trigger a cascade of events leading to the activation of CREB. One channel of interest is known as NMDA. In 1999 Joseph Z. Tsein, Ya-Ping Tang and their colleagues, then at Princeton University, discovered that increasing the number of NMDA receptors

DAVIES & STARR *Getty Images*

If we are smart enough to invent technology that increases brain capacity, we should use that advantage.

in the mouse hippocampus led to better performance on a spatial-memory task. Now researchers and pharmaceutical companies are pursuing NMDA receptor agonists (they combine with the receptors) as nootropes. At least a dozen new drugs of this kind are making their way toward clinical trials.

Scientists have known for years that more commonplace chemicals such as adrenaline, glucose and caffeine increase memory and performance. We all know it, too: procrastinators find clarity of mind in the adrenaline rush to meet a deadline; we try not to work "on an empty stomach"; and we are willing to pay a premium for a vente latte—all testimony to our appreciation of these legal activities.

Self-medicating with Starbucks is one thing. But consider the following. In July 2002 Jerome Yesavage and his colleagues at Stanford University discovered that donepezil, a drug approved by the FDA to slow the memory loss of Alzheimer's patients, improves the memory of the normal population. The researchers trained pilots in a flight simulator to perform specific maneuvers and to respond to emergencies that developed during their mock flight, after giving half the pilots donepezil and half a placebo. One month later they retested the pilots and found that those who had taken the donepezil remembered their training better, as shown by improved performance. The possibility exists that donepezil could become a Ritalin for college students. I believe nothing can stop this trend, either.

This anecdote reminds us that the unintended use and misuse of drugs is a constant. Trying to manage it, control it and legislate it will bring nothing but failure and duplicity. This fact of life needs to be aired, and our culture needs to reach a consensus about it. Aricept (the commercial name for donepezil) works, caffeine works, Ritalin works. Individuals will use such drugs or not use them, depending on their personal philosophy about enhancement. Some people like to alter their mental states; others do not.

My guess is that, on average, adults will choose not to use memory enhancers or the theoretically more obscure IQ or cognitive enhancers. Why? Because when memory is in the normal range, we adapt to its level and set our personal psychological life in that context. Increasing our memory capacity might send a ripple effect across the landscape of our daily lives. After all, we spend a good part of each evening trying to forget many of the day's memories. Over a lifetime we have built up our personal narrative based on the efficiency of our memory and our capacity to forget. Any significant or even slight change in these capacities will have to be integrated into the backbone of that narrative, changing the mental life of a person.

For a society that spends significant time and money trying to be liberated from past experiences and memories, the arrival of new memory enhancers has a certain irony. Why do people drink, smoke marijuana and engage in other activities that cause them to take leave of their senses? Why are psychiatry offices full of patients with unhappy memories they would like to lose? And why do victims of horrendous emotional events such as trauma, abuse or stressful relationships suffer from their vivid recollections? A pill that enhances memory may lead to a whole new set of disorders. Maybe the haunting memories

(The Author)

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IMAGE SOURCE/AGE FOTOSTOCK

of a bad experience will become ever present in consciousness after taking an enhancing pill. This problem and dozens of others may well be the outcome.

Of course, many steps precede success in drug development, and some critics doubt we will see these newer memory enhancers in our lifetime. Although studies on animal models find that certain drugs improve memory or performance on specific tasks, it is not clear that they would help humans. Many nootropes that were promising in lab animals have failed miserably in human clinical trials. Is this because millions of years of evolution have led to a human brain whose neurochemical concentrations are at optimal levels? Another hurdle for drugs is their potential to cause deleterious effects. Some accounts of mice with altered "smart" brains, for instance, show that the mice are not only more receptive to learning but are also more sensitive to pain.

Superintelligence

Enhancing memory is one issue. Making people smarter—more able to contemplate complex ideas with greater ease and facility—somehow seems more problematic. Do we want a nation full of Harvard graduates? On the surface it seems insane. But the basic science suggests that superintelligence is not far-fetched.

Defining what it means to be "smart" has frustrated psychologists for years. IQ and SAT tests, though long-standing indicators of academic success, are far from perfect indicators of success in the "real world." Intelligence tests, especially the IQ test, measure people's analytical skills, verbal comprehension, perceptual organization, working memory and processing speed. This type of intelligence is called psychometric intelligence, and although it is not the only type (some researchers believe in "multiple intelligences," even including athletic ability), it is *testable* and so remains one of our primary gauges.

In 1904 Charles Spearman, an English psychologist, reviewed the literature of the 19th century on intelligence and found that people who performed well on one test of intelligence seemed to perform well on all others. Spearman theorized the existence of a "general intelligence," which he termed *g*, that is used to process many domains and thus makes some people good at nearly all intelligence challenges. Many investigations since 1904 have supported Spearman's idea, and the current consensus among scientists and psychologists is that a *g* factor accounts for a great deal of the variance in intelligence test scores.

Recently geneticists have discovered that even such abstract qualities as personality and intelligence are coded for in our genetic blueprint. Studies of the genetic basis of *g* are just beginning, and because *g* most likely arises from the influence of many genes, the hunt will be a long one. Yet one study has already found that a gene on chromosome 6 is linked to intelligence.

So-called genetic brain mapping could help the search. Scientists are looking at the structural features (size, volume, and so on) of the brains of many individuals, including twins, familial relatives and unrelated individuals. By scanning all these brains in magnetic resonance imaging machines and looking at the differences, researchers have been able to determine which areas of the brain are most under the control of genes. These studies have emerged only in the past three to four years. Geneticists hope that once they know which brain areas are most affected by heredity, they can figure out which genes are responsible for those regions. With this kind of reverse mapping, the experts should be able to learn more about the genetics of intelligence.

Geneticists and neuroscientists seem to be in agreement: the genes that affect intelligence may be coding for the structure and functions of specific brain areas that underlie Spearman's *g*. When researchers combine brain mapping with IQ tests, they can begin to tease out the correlations between the size, structure, and volume of brains and intelligence. Neuroscientists have determined that overall brain size has a statistically significant correlation with IQ. More detailed investigations show that the amount of gray matter—consisting mainly of the cell bodies of neurons—in the frontal lobes varies significantly with differ-

DAVIES & STARR *Getty Images*

A nation of Harvard graduates may seem insane, but basic science suggests it's not far-fetched.

ences in intelligence scores. That suggests the frontal lobe may be the location of *g*.

Indeed, John Duncan and his colleagues at the Medical Research Council in Cambridge, England, who put smart volunteers through a multitude of mentally demanding tasks, found that the lateral part of the frontal lobe on both the left and right sides may be the resting place of general intelligence. While undergoing positron-emission tomography (PET) scans, Duncan's subjects selectively activated the lateral frontal cortex during several intelligence tests. Some researchers are skeptical of the importance of Duncan's study, saying it is "suggestive" at best because we do not yet fully understand what the frontal lobes do. But his findings solidify the fact that we have entered a new age in scientific history—an era that allows neuroscientists to investigate individual differences in intelligence, previously a field only for psychology.

Accordingly, a robust literature concerning neural differences in intelligence has arisen. Further support for the frontal lobe's role comes from the observation that people with frontal lobe damage usually score 20 to 60 points lower on IQ tests than others. These people also have deficits in what is called fluid intelligence, which decreases with age and includes abstract reasoning, processing speed, accurate responses during time constraints and use of novel materials.

Smarter or Just Faster?

The future is here. We have isolated one gene involved in intelligence, and others will follow. We know which parts of the brain are influenced by particular genes and which parts correlate with high IQ. We also know some of the neurochemicals involved in learning and memory. With such knowledge, we will gain understanding of what needs to be manipulated to increase intelligence in people who were not blessed with brilliance in their genomes or further increase the intelligence of those who were. Gene therapy could insert, delete, turn on or turn off genes that we find to be associated with intelligence.

My own belief is that none of this threatens our sense of self. The opportunities to enhance one's mental state abound. "Smart" describes how well one processes information and figures out tasks. Once something has been figured out, much work must then be applied to the solution, and the smartest people in the world rarely say that the task is easy. They have worked hard to achieve insight and solutions. So we may all get faster at figuring out new problems, but it is not clear what it would mean to get smarter. "Smarter" is frequently just another word for "faster."

Whatever happens, we can be sure that cognitive enhancement drugs will be developed and that they will be used and misused. But just as most people do not choose to alter their mood with Prozac and just as we all reorient our lives in the face of unending opportunities to change our sense of normal, our society will absorb new memory drugs according to each individual's underlying philosophy and sense of self. Self-regulation will occur. The few people who desire altered states will find the means, and those who do not want to alter their sense of who they are will ignore the drug potions. The government should stay out of it, letting our own ethical and moral sense guide us through the new enhancement landscape. M

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ANDY SACKS Getty Images

In infants, **Elizabeth Spelke** finds fundamental insights into how men and women think

By David Dobbs

Big Answers *from* Little People

If you had been blind all your life and could suddenly see, could you distinguish by sight what you knew already by touch—say, a cube from a sphere? Would flowers look like flowers you'd felt and faces like faces, or would they all be confusing patterns? How would you start to make sense of the many objects in your immediate view? If we are born knowing nothing, how do we come to know anything?

Harvard University psychologist Elizabeth Spelke takes these questions to the people who may be best able to answer them: babies. Spelke, whose sprawling laboratory in William James Hall teems with infants and researchers who are interested in them, has addressed some of the most intractable mysteries of human knowledge by interrogating little people who cannot yet talk, walk or even crawl. She has what she calls "an insatiable appetite" for assessing these young beings. Through Web pages, flyers and letters to day care centers and pediatricians' offices, her lab mates ask anyone and everyone for diminutive volunteers. They watch as the little subjects sit on their mothers' laps, tracking the stagecraft that Spelke and her cohorts use to gauge early understanding of numbers, language, objects, space and movement.

Spelke's findings have helped revise sharply our notion of what humans can make sense of in their first days, weeks and months. In doing so, she has offered some of the most substantial evidence to date regarding nature versus nurture and innate versus acquired traits. Spelke's discoveries about infant capabilities have become central to figuring out human cognition.

From her insights she has forged a bold, if still controversial, theory of "core knowledge," which asserts that all humans are born with basic cognitive skills that let them make sense of the world. This core knowledge, she says, underlies everything we learn throughout our lives and both unifies and distinguishes us as a species. Her theory prompted the American Psychological Association to honor her with its William James Fellow Award in 2000. And her work shows that, despite people's differences, we all have more in common than we recognize.

Spelke has shown that humans of all races and both sexes are born with similar "core knowledge."

Clarity, Not Confusion

The heart of Spelke's methodology is her observation of "preferential looking"—the tendency of infants and children to peer longer at something that is new, surprising or different. Show a baby a toy bunny again and again, and the baby will give it a shorter gaze each time. But give the bunny four ears on, say, its tenth appearance, and if the baby looks longer, you know the baby can discern four from two. The approach neatly bypasses infants' deficiencies in speech or directed movement and makes the most of the one thing they control well: how much time they fix their eyes on an object.

Spelke did not invent the scheme of studying preferential looking. That credit falls to Robert L. Fantz, a Western Reserve University psychologist who in the 1950s and early 1960s discovered that chimps and infants stare longer at things they perceive as unexpected. A researcher could gauge an infant's discriminatory and perceptual powers by showing the baby different, highly controlled scenarios, usually within a stagelike box, and observing what changes in the scenarios the infant would perceive as novel.

Using this basic technique, Fantz and others soon found that the infant's world was not, as pioneering psychologist William James had opined in 1890, a "blooming, buzzing confusion." Infants made sense of the world readily. For example, Fantz and others found that newborns could differentiate red from green, two-month-olds could discriminate all primary colors, and three-month-olds preferred yellow and red to blue and green. They found that a newborn could distinguish between her mother's face and a stranger's (unless both adults wore scarves over their hair), a four-month-old could recognize acquaintances, and a six-month-old could interpret facial expressions. By the 1970s psychologists recognized the first year of life as a far more explosive developmental period than they had ever considered it to be.

This work attracted Spelke when she was still an undergraduate at Radcliffe College. From 1967 to 1971, she studied with Harvard child developmental psychologist Jerome Kagan and quickly found herself hooked on the excitement of investigating the essential workings of human cognition by analyzing children. She continued that research while pursuing her Ph.D. in psychology at Cornell University, where the famed developmental psychologist Eleanor J. Gibson served as her graduate adviser and mentor. Gibson, one of only a handful of psychologists to win the National Medal of Science, had revealed much about infant cognition with some elegant experiments of her own. Her best known was the "visual cliff,"

ROSE LINCOLN *Harvard News Office (preceding pages)*

Researchers gauge an infant's perceptual, attentional and discriminatory powers by manipulating objects in highly controlled scenarios and recording what the baby focuses on (*left*) and which changes he or she perceives as novel (*right*).

KATHARINA CIEPLAK-VON BALDEGG

a piece of heavy glass extending from a tabletop. Would early crawlers avoid the apparent drop-off? Most do, a discovery that revised theories of infants' spatial understanding.

Under such tutelage, Spelke hit on her own landmark experiment. "At dinner one night," she recalls as we talk in her office at Harvard, "I was musing with a fellow student over whether, when babies look at and listen to something, do they perceive [the sight and sound of an event] as two separate things, or do they recognize a link between the two? How would you find that out? Suddenly, I had this image of two visual events going on side by side, like movies, and between them a loudspeaker that you could switch from the sound of one event to the sound of the other event. Would a baby turn to look at the event matching the soundtrack the speaker was playing? That experiment became my Ph.D. thesis. It was the first time I was able to start with a general question about how we organize a unitary world from multiple modalities and turn the question into a ridiculously simple preferential-looking experiment—which actually ended up working."

Sure enough, Spelke found that babies recognized the link between sound and sight, switching their gaze back and forth as the soundtrack changed. Thus began Spelke's career of pondering big questions with straightforward experiments on tiny people. The mixed-modality approach addressed the same "binding problem" faced by blind people who suddenly can see: How does the brain mesh the signals from different senses into a single impression? Spelke did not answer how, but she did show persuasively that this ability seems innate.

Native Knowledge

Over the years Spelke has conjured up many other elegant and productive investigations on object and facial recognition, motion, spatial navigation, and numerosity (grasping of numerical relationships). She is able to envision simple but powerful tests, she says, "because I think like a three-year-old." By showing babies objects in motion and then interrupting their logical speed or course, she has found that even a four-month-old infers that a moving object is supposed to keep moving. Yet it takes an eight-month-old to grasp the principle of inertia and expect the object's path to be consistent and smooth. By showing babies different arrays of disks, she has found that six-month-olds can distinguish eight from 16 and 16 from 32—but not eight from 12 or 16 from 24. By having babies watch a person reach for one of two objects on a table, she has found that although 12-month-olds know from an adult's gaze which object he will grab, eight-month-olds do not.

As the data from such clever designs mounted, Spelke began to develop her theory of core knowl-

(The Author)

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"The rich core knowledge we share gives us common ground," Spelke says, "something we badly need."

edge, often inspired by or collaborating with colleagues such as noted Massachusetts Institute of Technology linguist Noam Chomsky, French mathematician turned cognitive neuropsychologist Stanislaus Dehaene and Harvard psychologist Susan Carey. Core knowledge systems, Spelke says, are neuronal "modules" that are in place at birth for building mental representations of objects, persons, spatial relationships and numerosity. Somewhat akin to the "deep grammar" that Chomsky believes underlies all human language, these core knowledge modules enable all infants to organize their perceptions.

The sophistication of these systems in infants resembles that of modules in nonhuman primates, suggesting an ancient, evolutionary development; a six-month-old baby understands numbers, space, objects and faces much as a mature rhesus monkey does. As Spelke sees it, these cognitive tools underlie all the more complex skills and knowledge we master as we grow up—spoken languages, number manipulation and other abstract mental operations. Core knowledge forms the basis for the robust cognitive machinery that gets us through life. And we almost completely ignore it.

"Even for adults," Spelke says, "most of what we know that lets us negotiate the world, guide our choice of paths through the environment, understand whether a car down the street might hit us or whether a falling object will miss us, even what we say as we're conversing—most of that is completely unconscious. How many things do we do that we hardly think about? Most of what we do is like that. We operate on richly structured cognitive systems that aren't usually accessible to introspection. To me, this is one more sign that most of our cognitive workings are much like those of babies and are built on the core knowledge that we had as babies."

Equality of the Sexes

This view of Spelke's is what philosophers call a "nativist" theory—that certain of our traits are inborn. They are natural rather than nurtured. Spelke knows well that this puts her on a slippery slope. To speak of native abilities is to court speculation about native differences in those abilities. This past spring Spelke found herself involved in a hot controversy about such possible differences when she was repeatedly asked for her opinion of Harvard president Lawrence Summers's remarks that biological disparities might help explain why women occupy so few places in university math and science departments. Spelke, of course, was the natural choice to debate this topic, not only because she was a prominent, highly accomplished scientist at Summers's university but because she got there by studying precisely the innate abilities Summers wondered about. Although she hardly seems a scrapper by inclination, Spelke is quick-witted, funny, impressively well informed and eminently agile in conversation. And she rose quite gracefully to the task of popping Summers's thought balloon.

"If you look at things Summers's way," she says in her office, leaning forward in her chair with a sly grin, "then to study innate cognitive abilities, like I do, is supposedly to study gender differences. In fact, I didn't know we were studying gender differences at all, because we don't find any. But since the subject came up"—she spread her hands, clasped them, then sat back in her chair, smiling—"I was happy to tell him about our work."

Summers got an earful, if not directly, as Spel-

Spelke was plunged into controversy this past spring when Harvard University president Lawrence Summers (*opposite page*) remarked that biology might explain why women occupy so few college math and science jobs. The foundations for these disciplines, she said publicly, "develop equally in males and females."

KIRSTEN CONDRY

STEVEN SENNE *AP Photo*

After controversial remarks about women's abilities in math and science, Summers (*center*) announced that Harvard would spend $50 million to bolster female and minority faculty.

ke described in several interviews and in a high-profile public debate with her colleague and friend, Harvard psychologist Steven Pinker, how voluminous evidence from decades of research shows little if any inherently sex-based differences in infants or toddlers. At those early ages, when culture has the least effect but sex hormone levels are extremely high, no sex-based differences have shown themselves in a huge variety of skills that underlie mathematical thinking. For example: put a four-year-old in a distinctly shaped room, hide a block in a corner, have the four-year-old close his eyes and spin around, then have the child hunt for the block. Some of the children will quickly reorient themselves in the room and find the object, whereas others will not. Yet the percentages of boys and girls who succeed are identical. So although "there is a biological foundation to mathematical and scientific reasoning," as Spelke put it in her debate with Pinker, "these systems develop equally in males and females."

Spelke, an unabashed optimist, believes our growing understanding of cognitive abilities will eventually reduce, rather than inspire, divisions about our human qualities. "This idea that we have native abilities," she tells me, "some find threatening, for it seems to invite the idea that some types of people might be innately better endowed than others. If you're a nativist about basic core cognitive capacities, as I am, does that also lead you to be a nativist about, say, differences among the sexes? These claims of biological bases can proliferate to a point where they end up being invoked to explain everything. But you have to be very careful about what data you use." The information that seems to indicate sex differences, Spelke says, comes from problematic studies whose results are colored by cultural influences—everything from parents responding differently to girls and boys to university faculties viewing identical job applications more skeptically when the applicant's name is female. Summers must have taken that last point to heart: in May he announced that Harvard would spend $50 million over 10 years to recruit and support women and minorities on its faculty.

Meanwhile the expanding pile of data on infants, who are not tainted by culture, shows remarkable parity among sexes and races. "We're getting evidence for an intricate and rich system of core knowledge that everyone shares and that gives us common ground," Spelke declares. "In a world of so much conflict, I think that's something we badly need." **M**

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THE PSYCHOLOGY OF TYRANNY

POWER CORRUPTS, AND ABSOLUTE POWER CORRUPTS ABSOLUTELY—OR DOES IT?

BY S. ALEXANDER HASLAM AND STEPHEN D. REICHER

Images of inhumanity and atrocity are burned into our memories. Jewish men, women and children being herded into gas chambers. Entire villages destroyed by rampaging gangs in Rwanda. The systematic use of rape and the destruction of communities as part of "ethnic cleansing" in the Balkans. The massacre at My Lai in South Vietnam, the abuse of Iraqi prisoners in Abu Ghraib, and most recently, the carnage wrought by suicide bombers in Baghdad, Jerusalem, London and Madrid. Reflecting on these events, we inevitably ask: What makes people so brutal? Are they mentally ill? Are they the products of dysfunctional families or cultures? Or, more disturbingly, is anyone capable of taking part in collective ruthlessness given the right—or rather, the wrong—circumstances? Now the latest research, including possibly the largest social-psychology experiment in three decades, is providing a new window on these conundrums.

Joseph Stalin, Adolf Hitler, Idi Amin and Saddam Hussein had powerful personalities, but their success as tyrants also required social conditions that made their messages acceptable.

Questions about why groups can behave badly have driven some of the most significant developments in social psychology in the 60 years since World War II ended. Starting with the need to understand the psychological processes that made possible the horrors of the Holocaust, scientists have wanted to know how large numbers of apparently civilized and decent people can perpetrate appalling acts.

Initially theorists sought answers to group pathology in individual psychology. In 1961, however, German-born American historian and political philosopher Hannah Arendt witnessed the trial in Jerusalem of Adolf Eichmann, one of the chief architects of the Holocaust. She concluded that far from the defendant demonstrating a "perverted and sadistic personality" (as psychiatrists for the prosecution claimed), he was utterly unremarkable and disarmingly ordinary. Arendt pronounced Eichmann to be an embodiment of "the banality of evil."

Everyday Evil?

First published in 1963 in the *New Yorker,* Arendt's analysis was considered shocking and heretical. But a series of studies conducted around the same time supported her observations. In experiments at U.S. summer camps during the late 1950s, Muzafer Sherif, a Turkish-born American social psychologist, learned that normal schoolboys became cruel and aggressive toward former friends once they had been placed in different groups that had to compete over scarce resources. Even more striking were obedience studies carried out at Yale University in the early 1960s by Stanley Milgram. Ordinary, well-adjusted males who took part in a bogus memory experiment were told to deliver electric shocks of increasing magnitude to another person who posed as the learner. (In actuality, the learner, an accomplice of the experimenter, received no shocks.) Amazingly, every single "teacher" was prepared to administer "intense shocks" of 300 volts, and two thirds obeyed *all* the experimenter's requests, dispensing what they believed were 450 volts. Participants continued meting out punishments even after hearing the learner complain of a heart condition and yell in apparent agony. Milgram concluded: "Arendt's conception of the banality of evil comes closer to the truth than one might dare to imagine."

The vivid culmination of this line of inquiry was the Stanford prison experiment, carried out in 1971 by Stanford University psychologist Philip G. Zimbardo and his colleagues. The researchers randomly assigned college students to be either prisoners or guards in a simulated prison in the basement of the campus psychology building. The goal was to explore the dynamics that developed within and between the groups over a two-week period. The study delivered these dynamics in abundance. Indeed, the guards (with Zimbardo as their superintendent) exerted force with such harshness that the study was halted after only six days.

The experimenters concluded that group members cannot resist the pressure of their assumed stations and that brutality is the "natural" expression of roles associated with groups who have unequal power. Accordingly, two maxims,

PRECEDING PAGES: MARC CARTER *Getty Images;* THIS PAGE: HULTON-DEUTSCH COLLECTION CORBIS *(Stalin);* BETTMANN CORBIS *(Hitler);* ALAIN NOGUES *Sygma Corbis (Amin);* JACQUES PAVLOVSKY *Corbis (Hussein)*

> Scientists have wanted to know how apparently civilized people can perpetrate appalling acts.

The "banality of evil" is clear in the hotel room in Rwanda (*left*) that served as the ordinary-looking setting for launching a plan for genocide (*below*).

STUART FRANKLIN *Magnum Photos (top);* PATRICK ZACHMANN *Magnum Photos (bottom)*

which have had immense influence at both a scientific and a cultural level—and which are taught as received knowledge to millions of students around the world every year—are routinely drawn from the Stanford experiment. The first is that individuals lose their capacity for intellectual and moral judgment in groups; hence, groups are inherently dangerous. The second is that there is an inevitable impetus for people to act tyrannically once they are put in groups and given power.

Reexamining Group Power

The weight of the Stanford prison experiment lies in both its dramatic findings and the simple, stark conclusions that have been drawn from it. Over the years, however, social psychologists have developed doubts about the resulting received wisdom.

First, the idea that groups with power automatically become tyrannical ignores the active leadership that the experimenters provided. Zimbardo told his guards: "You can create in the prisoners … a sense of fear to some degree, you can create a notion of arbitrariness that their life is totally controlled by us.… They'll have no freedom of action, they can do nothing, say nothing that we don't permit.… We're going to take away their individuality in various ways."

Second, we know that groups do not perpetrate only antisocial acts. In studies—as in society at large—the group often emerges as a means to *resist* oppression and the pressure to act destructively. In variants of Milgram's obedience trials, participants were much more likely to defy the experimenter when they were supported by confederates who were also disobedient.

In addition, research after Stanford has confirmed the prosocial and enriching aspects of groups. One particularly influential approach to understanding groups in psychology today is the social identity theory developed in 1979 by social psychologists John Turner, now at the Australian National University, and Henri Tajfel, then at Bristol University in England. This theory holds that it is mostly in groups that people—particularly the individually powerless—can become effective agents who shape their own fate.

When individuals share a sense of identity (for example, "we are all American," "we are all Catholic"), they seek to reach agreement, they like and trust one another more, they are more willing to follow group leaders, and they form more effective organizations. This fact is shown, for example, in

extensive studies of cooperation in groups conducted recently by Steven L. Blader and Tom R. Tyler of New York University. As a result, people can pull together to create a social world based on their shared values—instilling a state of "collective self-realization," which is good for psychological health. Having the social support to control one's fate results in higher self-esteem, less stress, and lower levels of anxiety and depression.

People who share a sense of identity in a group demonstrate two social features. First, they do not lose the capacity for judgment; instead the basis for their decisions shifts from their individual notions to their commonly held understandings. As field studies by one of us (Reicher) have shown (a summary appears in the *Blackwell Handbook of Social Psychology: Group Processes*), even the most extreme collective actions, such as a riot, reveal a pattern of behavior that reflects the beliefs, norms and values of the group involved. Second, people's responses vary depending on which group membership is most important to them in any given situation. For instance, the norms and values that we use as employees in the workplace may differ from those that govern us as believers at our place of worship, as activists at a political rally or as patriots at the raising of the flag.

In contrast to the Stanford conclusions, however, social identity theorists have long argued that people do not automatically accept the group memberships that others give them. Quite frequently people distance themselves from groups, especially those that are devalued in society. For instance, in the 1970s Howard Giles and Jennifer Williams, both then at Bristol University, pointed out that many women respond to inequality by downplaying their gender, emphasizing their personal qualities and seeking success as individuals. Only when they believe that they cannot escape—that is, when boundaries between groups are seen to be impermeable, as feminists argued when they identified the "glass ceiling"—will they identify with the devalued group and act collectively. In addition, they will be prepared to use their collective power to challenge the status quo and try to improve the position of their group only if they view the social system as unstable.

A large body of research, including controlled laboratory studies, extensive surveys and detailed field observations, supports the social identity perspective (for a review, see *Social Identity*, edited by Naomi Ellemers of Leiden University in the Netherlands and her colleagues). Yet until recently there was no single study in the mold of Sherif, Milgram or Zimbardo that might illustrate and combine the theory's various propositions in a comprehensive and compelling manner. What is more, it seemed impossible to conduct such a study. Despite all the doubts surrounding Stanford, its very severity seemed to put further studies of its type off-limits.

This situation recently changed with the BBC prison experiment. The two of us collaborated with the British Broadcasting Corporation, which funded the research and broadcast the findings in four one-hour documentaries. Our first challenge was to develop ethical procedures that would ensure that, though strenuous, the study would not harm participants. We put into place a raft of safeguards, including on-site clinical psychologists and a round-the-clock independent ethics committee. As the committee's report concludes, we showed that it is possible to conduct dynamic field studies that are also ethical.

> We aimed to represent institutions in which one group has more **power and privilege** than the other.

The Experiment

Like Stanford, the BBC experiment divided men randomly into guards and prisoners within a custom-built environment. We modeled the setting on a prison, but more broadly we aimed to represent a general class of institutions—such as an office, a barracks, a school—in which one group has more power and privilege than the other. Throughout the study we watched the behavior of participants using unobtrusive cameras. We monitored their psychological states

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through daily tests. We even checked their well-being by using saliva swabs to measure levels of cortisol—an indicator of stress.

Although our experiment followed the same basic paradigm as that of Stanford, it differed in a number of ways. Unlike Zimbardo, we did not assume any role within the prison, so we could study the group dynamics without directly managing those interactions. Second, we manipulated features of social hierarchy that social identity theory predicts should affect prisoners' identification with their group and the forms of behavior in which they subsequently engage. Most significant, we varied the permeability of group boundaries by initially allowing, but then eliminating, opportunities for promotion from prisoner to guard. We expected that given the possibility of advancement, prisoners would try to reject their prisoner identity and work independently to improve their position. We anticipated that this strategy would reinforce the status quo and allow the guards to maintain ascendancy. But after we ruled out promotion (on day three), we thought the prisoners would start collaborating to resist the guards' authority.

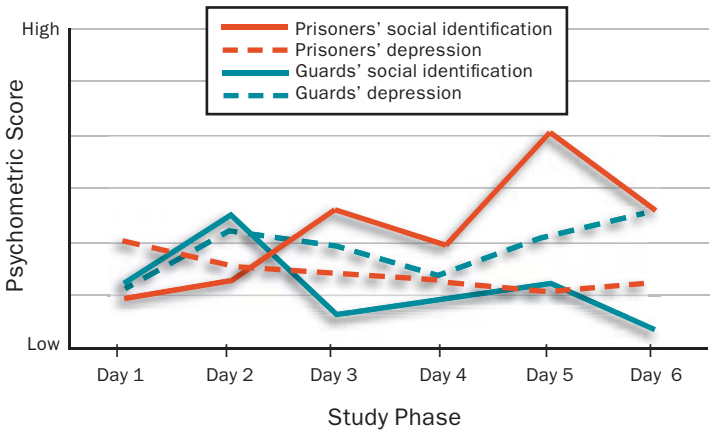
The results upheld our predictions. At first the prisoners were compliant and worked hard to improve their situation. They started to see themselves as a group and become uncooperative with the guards only when they learned that, no matter how industrious they were, they would remain prisoners. What is more, this shared identity led to improved organization, effectiveness and mental well-being. As the study progressed, the prisoners became more positive and empowered.

The guards, however, surprised us. Several guards were troubled by the idea that groups and power are dangerous, and they were reluctant to exercise control. Uncomfortable with their task, they disagreed with other guards as to how their role should be interpreted and never developed a shared sense of identity. This lack of identity led to a dearth of organization among the guards—which in turn meant that they became increasingly ineffective at maintaining order and increasingly despondent and burned out. As the study progressed, the guards' administration became ever more toothless.

After six days, the prisoners collaborated to challenge the fragmented guards, leading to an organized breakout and the collapse of the prisoner-guard structure. Then, on the ruins of the old system, both prisoners and guards spontaneously established a more equal system—in their words, "a self-governing, self-disciplining com-

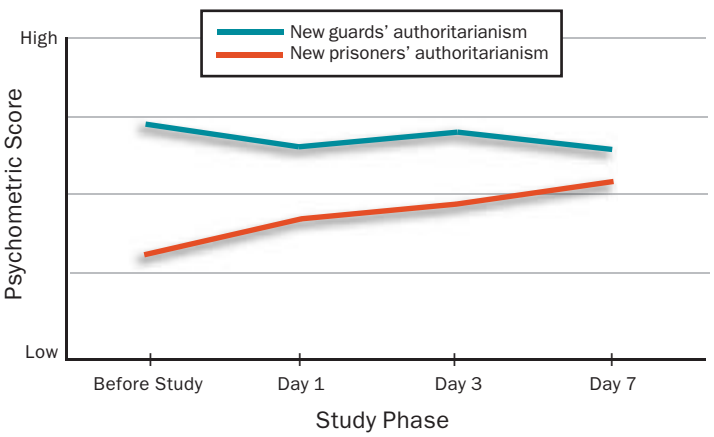
BRITISH BROADCASTING CORPORATION (*photograph*); PATTI NEMOTO (*graphs*)

Shifts in Group Dynamics



In the BBC prison study, "prisoners" developed a strong sense of shared identity, particularly after they could not earn promotion to "guards." As a result, they became less depressed and began to challenge the guards. In contrast, the guards did not develop a sense of shared idenity and became weaker as a group and more depressed.

Changes in Authoritarianism



Guards who wanted to institute a new regime after an egalitarian commune collapsed had been more authoritarian-minded than other participants at the start of the study. By the time this new group of guards proposed their coup on day 8, their views were more acceptable because other participants had become more authoritarian.

mune." Once again, though, some members were bothered by the idea of using power. They did not discipline individuals who neglected to perform assigned tasks and broke the commune's rules.

At this point, we got a second surprise. Supporters lost faith in their ability to make the commune work, leaving its members in disarray. In response, a number of former prisoners and former guards proposed a coup in which they would become the new guards. They asked for black berets and black sunglasses as symbols of a new authoritarian management that they wanted to impose. They talked of re-creating the guard-prisoner divide but this time ensuring that the prisoners "toed the line"—using force if necessary. We expected those who had supported the commune to defend the democratic arrangement they had put in place. But nothing of the kind happened. Instead they lacked the individual and collective will to defy the new regime. Psychometric data also indicated that they had become more authoritarian-minded and more willing to accept strict leaders.

In any event, the coup never occurred. For ethical reasons, we could not risk the type of force witnessed in the Stanford study, and so we brought the study to a premature close on the eighth day. But whereas the outcome resembled that of Stanford, the path our participants took to reach that point was very different. In particular, the specter of tyranny was very clearly not a product of people acting "naturally" in terms of the groups to which they had been assigned. Instead it arose from the *failure* of those groups: for the guards, the inability to develop a cohesive bond and, in the case of the commune, the breakdown in the attempt to turn collective beliefs into reality.

Lessons for Society

Why did participants who had rejected mild inequalities imposed on them at the start of the study, and who had fought so hard to establish a democratic system, end up shifting toward a self-supported tyranny? The answers lie in a basic corollary to our arguments. Groups, we have discussed, are ultimately about collective self-realization. They use social power to make an existence in the image of their shared beliefs and values. But when groups cannot produce such a working order, their members become more willing to accept other social structures—even if these new systems violate their existing way of life. Thus, when the guards could not impose their authority, they became more willing to agree to democracy. More ominously, though, when the commune fell apart, its members became less

IAN BERRY *Magnum Photos*

Protesters in South Africa show how membership in a group can give individuals the collective power to speak out against oppressive regimes.

motivated to defend democracy against tyranny.

From this study and other research into social identity processes, we can draw conclusions that have important implications for academia and society at large. In general terms, we concur with Sherif, Milgram, Zimbardo and others that tyranny is a product of group processes, not individual pathology. Yet we disagree about the nature of these processes. From our standpoint people do not lose their minds in groups, do not helplessly succumb to the requirements of their roles and do not automatically abuse collective power. Instead they identify with groups only when it makes sense to do so. And when they do, they actively and knowingly attempt to implement collective values—the way in which they exercise power depends on these values. In short, groups do not deny people choice but rather provide them with both the grounds and the means to exercise choice.

> People do not lose their minds in groups and do not automatically abuse collective power.

Of course, this argument does not deny that people can do terrible things in groups. But not all groups in charge and certainly not all prison guards are brutal. To propose that there is something inherent in group psychology that mandates excessive cruelty is to take the spotlight off the specific factors that lead particular groups to become vicious, brutish and tyrannical.

Two interrelated sets of circumstances can lead to a tyrannical group dynamic. The first arises from the success of groups that have oppressive social values. It has been pointed out, for instance, that the worst atrocities occur when people believe they are acting nobly to defend against a threatening enemy. One might wonder: How do they come to hold those beliefs? In turn we ask: What is the role of national leaders in demonizing out-groups—such as Jews, Tutsis or Muslims? What about immediate superiors of military units who actively encourage brutality or passively condone it? What part do ordinary men and women play when they laugh or turn a blind eye to an out-group member who is being humiliated? As our questions imply, we believe that people at every level of the group help to foster a collective culture of hate and are responsible for its consequences.

Less straightforwardly, the second constellation of factors that can give birth to tyranny occurs when groups who seek to instill democratic and humane social values do not succeed. When a social system collapses, people will be more open to alternatives, even those that previously seemed unattractive. Moreover, when the collapse of a system wreaks such havoc that a regular and predictable social life becomes impossible, the promise of a rigid and hierarchical order becomes more alluring. Thus, the chaotic failure of the democratic Weimar led to the rise of Nazism; the deliberate divisions imposed by ruling powers facilitated the ascendancy of brutalizing regimes in postcolonial Africa and in the post-Soviet Balkans; and the suppression of postwar organization paved the way to the reemergence of antidemocratic forces in Iraq. In each case, the rejection of democracy can be traced back to political strategies that deliberately sought to break down groups and strip them of power. Rather than striving to make people fearful of groups and power, we suggest, people should be encouraged to work together to use their power responsibly.

To the extent that received wisdom encourages policymakers to foment the very conditions that can promote oppressive regimes, that thinking may be not only intellectually limited but downright dangerous. It was certainly perilous for the participants in the BBC prison experiment. Their tragedy was to neglect the reasonable exercise of power for fear of tyranny. As a bitterly ironic consequence, they set up the very conditions whereby the tyranny they feared came back to haunt them. M

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Judging Amy and Andy

Contrary to conventional wisdom, we can size up people pretty well based on first impressions

By Katja Gaschler

It took Amy only a few minutes to make up her mind: "I've got absolutely nothing in common with this guy." She wasn't sure why, but she was convinced. Was it his two-day stubble? The tattered jeans? Perhaps the way he stared at her while they talked? In any case, after a mere five minutes Amy was already wishing she had never agreed to this blind date with Andy. Now she would have to spend several hours in a bar with a guy who didn't understand why sports don't do it for her and why she prefers to read. "I know his type," she sighed to herself. "Conceited, careless. I'll bet he's going to tell me all about rock climbing and what a success he is. This is going to be a long evening."

Is Amy right? Or has she misjudged? After all, for decades psychologists have told us that people should not rate others based on looks or first impressions—we should not judge a book by its cover. Too often we subconsciously or even consciously adhere to stereotypes. To Amy, stubble represents laziness and torn jeans sloppiness and immaturity, and together they perhaps belie a guy who is trying too hard to look casually cool when a shave and slacks would do much better. And Andy's excessive talk about sports shows that he is

ALAN POWDRILL *Photonica/Getty Images*

just another guy who is self-absorbed with his own machismo. Yet social psychologists have warned that such compartmentalized thinking closes our minds and distorts our vision of reality. We also tend to generalize about a person's character from his behavior in a particular situation. If a cashier looks dour, we may conclude that he probably hates people. Researchers call such unjustified conclusions "fundamental attribution errors."

But are we really that far off in judging people by their looks and deeds? New psychological work shows that if we engage in only a few minutes of thoughtful observation we can reach surprisingly accurate conclusions about strangers, even when they are not in the room. Researchers point out that the conventional wisdom about the fallibility of first impressions was based on very little study. Few psychologists examined the phenomenon of first impressions, because they were unwilling to risk years of work only to reach what seemed to be common truisms.

ity. These impediments have lessened in recent years, however, as several methods have been developed that allow individuals to conveniently gauge their fellows.

The device that has risen to greatest prominence is the so-called five-factor, or "big five," model. Psychologists originally developed the model to help them consistently describe patient personalities and possible personality disorders by mathematically combining five descriptive factors in various ways. People who undergo clinical assessment and fall at the extreme ends of a scale for a given trait, for example, may be likely to have a disorder linked to that trait. Researchers have figured out how to use the same factors, however, to assess the appropriateness of first impressions.

The five factors used to analyze a person under scrutiny are known by the acronym OCEAN: openness to experience, conscientiousness, extroversion, agreeableness and neuroticism. In general, openness measures how willing a person

Psychologists have developed several methods that allow us to conveniently gauge others.

Furthermore, according to a recent survey by psychologists Joachim I. Krueger of Brown University and David C. Funder of the University of California at Riverside, prior research that intended to uncover evidence of misjudgment was almost always likely to find it because of flawed test design. The new, though still controversial, view is that with a little savvy observation, many of us are quite good at sizing up other people.

Quantifying Judgment

As soon as two strangers meet, they begin to speculate about each other. Hairstyle, facial expressions, figure, clothing, gestures—all these cues transmit signals that we evaluate within minutes or even seconds. And as soon as the other person speaks, a flood of additional information reaches us: How loud is his voice? Is it shaky or firm? How carefully does he choose his words?

Are these signs enough for us to form an opinion of the other person's personality? Arriving at a scientific answer is tricky, in part because it is difficult for researchers to quantify the accuracy of a judgment. For a long time, psychologists could not even agree on a definition of personal-

is to adjust his or her habits or views. Conscientiousness reflects how much the individual takes other people into account when making decisions. Extroversion ranks how outgoing someone is with others and how willing he or she is to explore new situations. Agreeableness indicates how well the person gets along with others. And neuroticism rates the person on a scale running from stable to anxious to volatile.

Since this model was first embraced in the early 1990s, several psychologists have tried to weed out the overlapping factors and have proposed other, more streamlined sets, such as the psychoticism-extroversion-neuroticism, or PEN, theory developed soon after by the late renowned University of London psychologist Hans J. Eysenck. In the past five years or so, still others have adapted these models to study how well test subjects perform when assessing people they meet for the first time. By introducing subjects to volunteers and having them fill out questionnaires afterward or by videotaping first encounters, the researchers have cast new light on how well we judge our fellow human beings. They have also created some schemes we all can use to size ourselves up [*see box on page 56*].

PAUL THOMAS *Image Bank/Getty Images*

Character can be gleaned from a person's office. Numerous personal objects (*left*) suggest an extrovert; tidiness (*right*) suggests discipline and dependability.

Telltale Clues to Character

Psychologist Samuel D. Gosling of the University of Texas at Austin is a leader in the field of assessing how well we evaluate others. He has taken his rubrics into some novel arenas. According to Gosling, it is not even necessary to be in the company of another person to make a reliable estimation about some of his or her traits; it is possible to get an impression by noting the person's external trappings.

The first set of signs denotes "identity claims"—symbols that an individual consciously creates to communicate to the outside world. For example, a student who decorates his dorm room with a picture of Albert Einstein is trying to convey something about his intellectual values. Some students cover their walls with rock music posters and beer ads, whereas others may only hang bookshelves to hold neat rows of classic novels. Identity claims can be more subtle, too, such as when someone displays photographs of friends to demonstrate sociability.

"Behavioral residues," in contrast, are left unconsciously: compact-disc cases that happen to be scattered across a desk reveal musical taste, whereas dirty soccer socks on the floor are evidence of involvement in sports (and a lax attitude about tidiness). Sometimes behavioral residues are not easy to differentiate from identity claims—hang-gliding equipment may be perched in the corner of a room because there was no space in the closet or because the owner wants to flaunt his love of adventure.

Let us assume that Amy had been able to peek into Andy's apartment or office before their uncomfortable date began. Would she have turned him down ahead of time? In one study by Gosling, eight test subjects each had a chance to look at offices belonging to 70 different workers. Because the workers were not permitted to change anything before these inspections, the test subjects not only got a sense of each space's decor but also its state of organization. In addition, each worker had completed a personality questionnaire and named two good friends who were then asked to evaluate his or her character. The results served as a reference against which the

(The Author)

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Who Are You?

Before you can discern whether other people judge your personality accurately, you have to be clear-eyed about your own character traits. Below is a self-test developed by psychologist Samuel D. Gosling of the University of Texas at Austin called the Ten Item Personal Inventory. Write a number next to each statement that indicates the extent to which you agree or disagree with that statement. Rate the terms as a pair, even if one applies more strongly than the other. Then use the key at the bottom to see where you lie on the "big five" traits that many psychologists use to assess personality—and possible disorders.

Disagree strongly	Disagree moderately	Disagree a little	Neither agree nor disagree	Agree a little	Agree moderately	Agree strongly
1	2	3	4	5	6	7

I see myself as:

1. ____ Extroverted, enthusiastic

2. ____ Critical, quarrelsome

3. ____ Dependable, self-disciplined

4. ____ Anxious, easily upset

5. ____ Open to new experiences, complex

6. ____ Reserved, quiet

7. ____ Sympathetic, warm

8. ____ Disorganized, careless

9. ____ Calm, emotionally stable

10. ____ Conventional, uncreative

Big-Five Trait:

Openness: This trait is strong for high values on question 5, low values on question 10.

Conscientiousness: Strong if high score on question 3, low score on question 8.

Extroversion (outgoing and sociable): High on question 1, low on question 6.

Agreeableness: High on question 7, low on question 2.

Neuroticism: High on question 4, low on question 9.

eight subjects' judgments could be compared.

The subjects' assessments of the workers' personalities were remarkably accurate, especially when it came to predicting how open and extroverted each worker was. They also were frequently on the mark when it came to "conscientiousness" and "emotional stability."

The subjects also supplied Gosling with comprehensive lists of observations they had used in their assessments. Gosling's team tried to determine which of these indices were most fundamental. A room that was clean and well organized was seen as a strong sign of conscientiousness. Inventive decorations seemed to indicate openness. If Amy had seen Andy's office, which is in a constant messy state, she may have questioned his compatibility much earlier.

Exposed at Home

Gosling has also shown that strangers can gauge a person's character by looking at her home and even her Web site. Because employees generally don't set the floor plan of their own offices, a person's living space should be an even better environment from which to glean insight. In a separate study overseen by Gosling, test subjects looked at 80 student apartments. They correctly evaluated a clean and tidy space as an indication of discipline and dependability. The range of visible books and periodicals, but not their quantity, was also a reliable indicator of "openness"—willingness to tolerate other people's views.

Surprisingly, the test subjects were also able to evaluate—to some extent—the emotional stability

GHISLAIN AND MARIE DAVID DE LOSSY *Image Bank/Getty Images*

and agreeableness of the occupant. No reliable set of observations correlated with the correct assessments, however, so it is still unclear how the subjects arrived at their conclusions. Gosling says it is possible that they in part fell back on "correct prejudices"—for example, that women tend to rate themselves and be rated by others as more emotionally volatile than men.

Of course, it is unlikely that Amy would have inspected Andy's bedroom before their first date. But she could certainly be angry with herself that she took her girlfriend's sketchy information about him at face value (nice guy, recently on the rebound) and did not try to find out more. If she had done an Internet search, she would have found his personal home page and discovered that he has read many books by beatnik Charles Bukowski, which might partially explain a penchant for tattered clothing but also an interest in literature.

But how much does the usually well-groomed image projected on a Web page tell us about a person's actual character? A lot, if the content is scrutinized for sense and not for any specific details. Items on a Web page have been deliberately placed there—they are identity claims. But what is placed, how it is arranged, what is stressed and linked give insight into character. Gosling and an assistant instructor in his department, Simine Vazire, recently published a study of Web page attributes and found that a person's home page is a good barometer of openness, followed by conscientiousness, extroversion and emotional stability. Agreeableness is not reflected well. Home pages give at least as much information as the state of a person's office, Gosling says. Web sites can even provide some behavioral residues—for example, inadvertent spelling or grammatical errors—that may influence a viewer's judgment.

Be Mindful, Not Quick

As telling as Web sites, homes and offices can be, face-to-face interaction is still the strongest source of an accurate judgment. Even though Amy knew almost nothing about Andy, she formulated a definite image within just a few minutes. A growing number of recent studies indicate that although individuals differ in their degree of social perception, the ability to reach good conclusions from first impressions is relatively well developed in most people.

The key is understanding that some kind of rational process must be used to reach that conclusion. Quick glances, gut reactions and clichés do not suffice. And misjudgments are likely if a meeting is too short or contains too few indicators to draw on. For example, a meta-analysis conducted in 2002 confirms that we tend to judge good-looking people as more intelligent than others. But what personnel department would rely on such uncertain data to decide on whom to hire?

> The range of books and magazines in a man's home can indicate his tolerance for other people's views.

Few of us are so naive as to judge intelligence solely on appearance. In 1995 Peter Borkenau, now at Martin Luther University Halle-Wittenberg, and his colleague Anette Liebler, now at the Center for Community Psychiatry in Detmold, Germany, demonstrated how quickly appearance pales in significance as an indicator when a person begins to speak. Recently Borkenau published another study showing that we need to listen to someone read for only three minutes to construct a rather accurate image of his or her intellectual capacities. Before Amy ventures out again, she might consider phoning her date and asking him to read the newspaper headlines to her.

Contrary to what might have been expected from their initial disconnects, Amy and Andy ended up having a pretty good time. Andy realized that Amy was not responding to his sports stories. Instead he began to tell her about his trip to China. He also listened attentively as she talked about her work in the hotel industry, and he asked about her taste in literature.

Amy's initial impression—that Andy may not be a paragon of dependability—was confirmed in their conversation. And her suspicion that he really did not fit the image she was looking for in a future partner held, too. But it didn't mean she couldn't enjoy the evening. M

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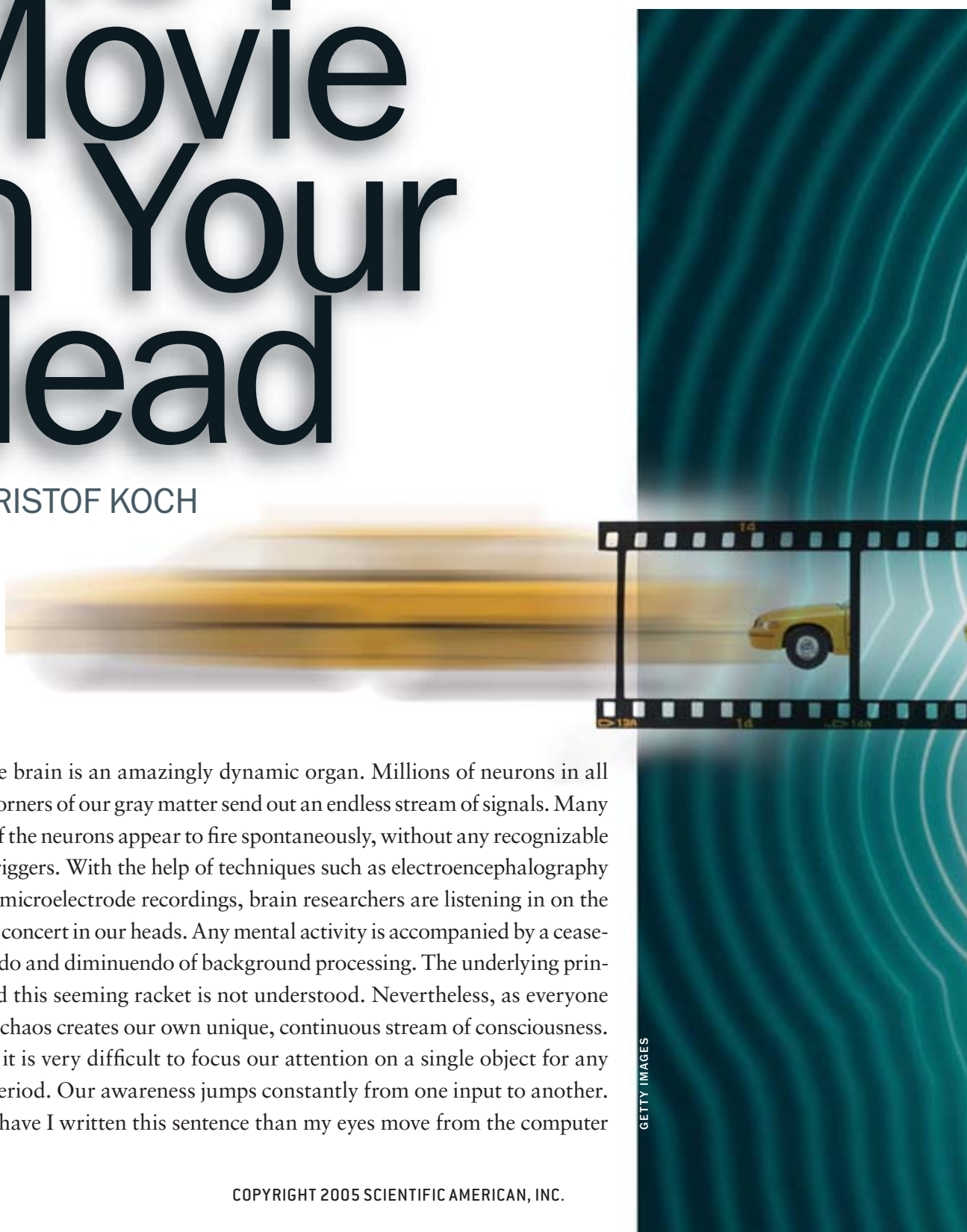
The Movie in Your Head

IS CONSCIOUSNESS A SEAMLESS EXPERIENCE OR A STRING OF FLEETING IMAGES, LIKE FRAMES OF A MOVIE? THE EMERGING ANSWER WILL DETERMINE WHETHER THE WAY WE PERCEIVE THE WORLD IS ILLUSORY

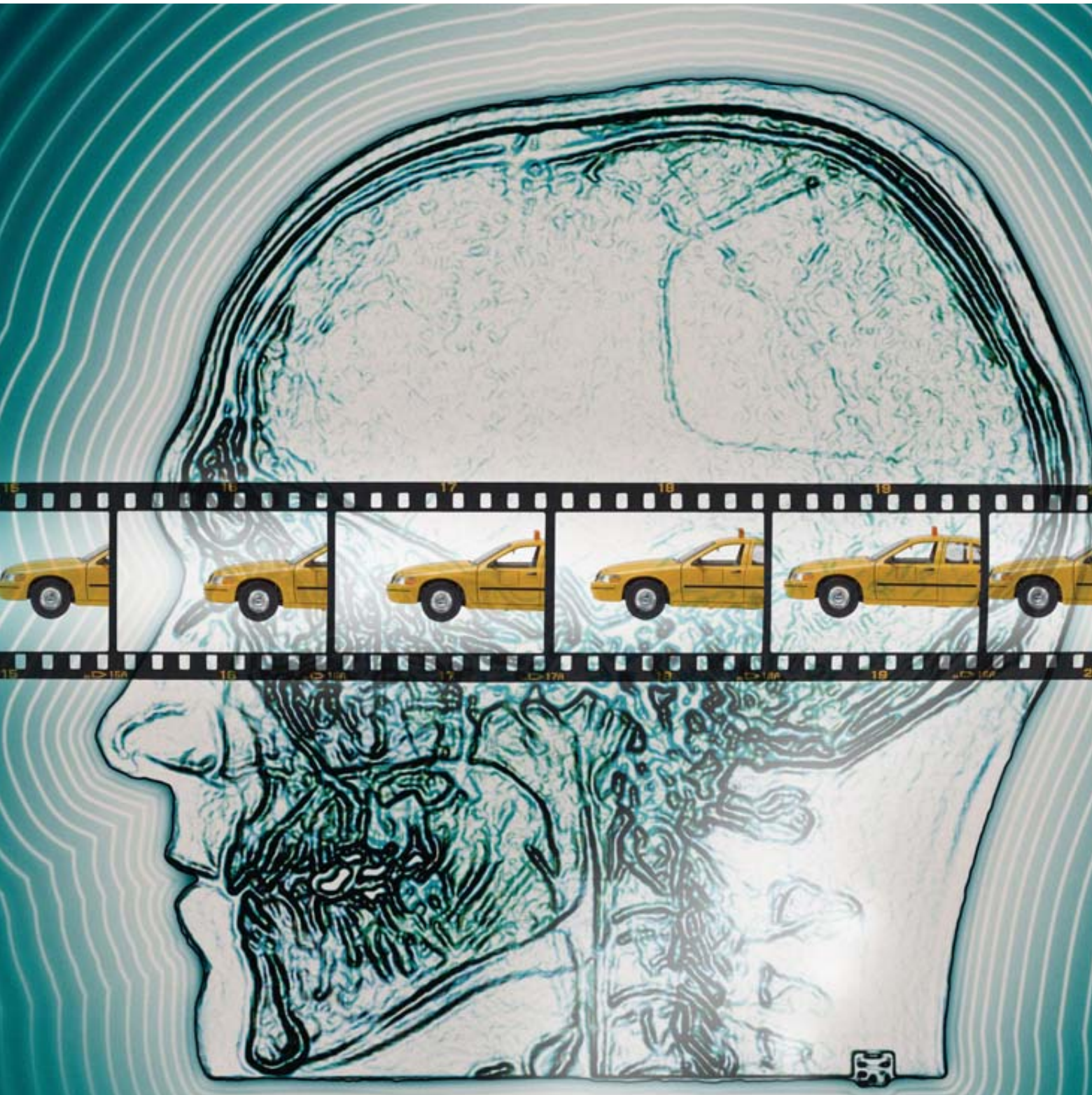
BY CHRISTOF KOCH

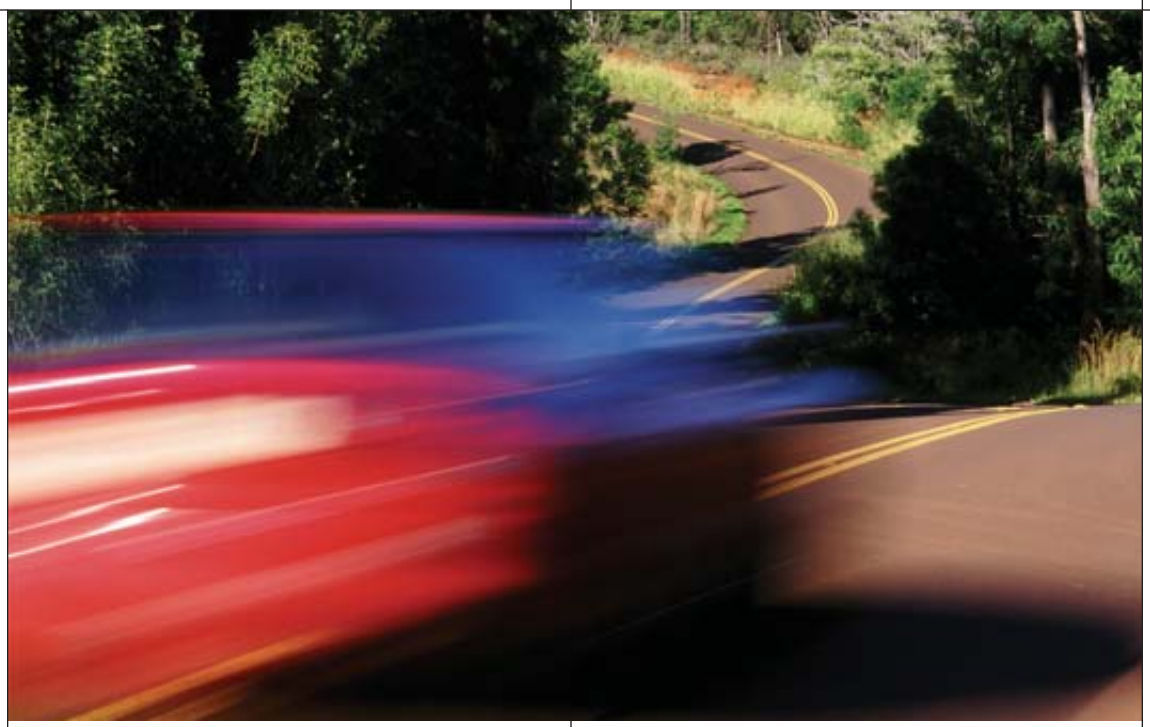


GETTY IMAGES

The brain is an amazingly dynamic organ. Millions of neurons in all corners of our gray matter send out an endless stream of signals. Many of the neurons appear to fire spontaneously, without any recognizable triggers. With the help of techniques such as electroencephalography (EEG) and microelectrode recordings, brain researchers are listening in on the polyphonic concert in our heads. Any mental activity is accompanied by a ceaseless crescendo and diminuendo of background processing. The underlying principle behind this seeming racket is not understood. Nevertheless, as everyone knows, the chaos creates our own unique, continuous stream of consciousness.

And yet it is very difficult to focus our attention on a single object for any extended period. Our awareness jumps constantly from one input to another. No sooner have I written this sentence than my eyes move from the computer





Different brain regions process an object's color, sound, speed and direction with differing delays, yet the brain rapidly reaches a unified impression because it has no mechanism for registering the asynchrony.

ML SINIBALDI *Corbis*

screen to the trees outside my window. I can hear a dog barking in the distance. Then I remember the deadline for this article—which isn't going to be extended again. Resolutely, I force myself to type the next line.

How does this stream of impressions come to be? Is our perception really as continuous as it seems, or is it divided into discrete time parcels, similar to frames in a movie? These questions are among the most interesting being investigated by psychologists and neuroscientists. The answers will satisfy more than our curiosity—they will tell us if our experience of reality is accurate or a fiction and if my fiction is different from yours.

Did You See That Animal?

Nothing that we perceive, think or feel falls out of the blue into our inner eye. Each mental feat is grounded in particular processes in the brain. Scientific research methods are not well suited to studying the neuronal processes that accompany our conscious experience. Yet much has been learned concerning the neural basis of subjective experience. My old friend and colleague, the late Francis Crick, and I coined a term for these fascinating processes: neuronal correlates of consciousness, or NCCs—the set of firings among neurons that correlates with each bit of awareness that we experience.

How are we to understand the creation and disappearance of such NCCs? Do they spring—like Athena from the head of Zeus—completely formed from unconscious brain activity, only to dissolve instantly again? Such an all-or-nothing principle would certainly conform to our subjective experience, in which a thought or sensation is suddenly there and then disappears. On the other hand, NCCs might build up over a longer time until they intrude into our awareness and may then only slowly fade until they are so slight that we can no longer perceive them.

Something like this second theory is advanced by psychologist Talis Bachmann of the University of Tartu in Estonia. Bachmann believes that consciousness for any one sensation takes time, comparable to the development of a photograph. Any conscious percept—say, the color red—does not instantly appear; we become aware of it gradually. A large body of experimental work seems to support this hypothesis.

Measuring reaction times is the most obvious approach to studying the temporal structure of consciousness. As early as the 19th century, psychologists exposed test subjects to flashes of light that varied in duration and intensity. They were attempting to discover how long an individual had to be exposed to a stimulus to perceive it consciously and how close in time two stimuli had to be to be perceived as one continuous sensation.

Today researchers flash a small black bar on a computer screen and ask subjects to press a button as soon as they recognize whether the bar is vertical or horizontal. Measured this way, however, the reaction time includes not only the interval it takes for the eye and brain to process the stimulus but also how long it takes for the

desired motor response—pressing the button.

To separate these components, researchers such as Simon J. Thorpe of the Brain and Cognition Research Center in Toulouse, France, measure so-called evoked potentials—changes in the electrical activity of neurons. This brain signal can be captured by electrodes attached to the scalp, as in an EEG recording. In one experiment, subjects were asked to decide quickly whether an image that flashed on a screen for fractions of a second contained an animal or not. This task did not prove difficult, even though they had no idea what kind of animal would be projected.

It became evident that the individuals needed less than half a second to give the correct answer. The time was about the same when they were asked to press a button to indicate whether an image showed a car or another means of transportation. The researchers then compared the brain reactions triggered by the animal images with those elicited by scenes containing no animals. In the initial fractions of a second after presentation, the EEG patterns were nearly identical.

It takes approximately 30 to 50 milliseconds for nerve impulses to travel from the eye's retina to the visual centers of the cerebral cortex at the back of the head. By 150 milliseconds, the evoked potential in response to animal images diverged from the electrical brain potential following nonanimal images. In other words, after about one tenth of a second something in the cerebral cortex began to distinguish animal from nonanimal pictures. Given that the processing time of lone neurons is in the millisecond range, this categorization is remarkably swift and can be accomplished only via massive parallel processing.

This result does not mean, however, that the information "animal" or "not animal" is consciously accessible within 150 milliseconds. Sight occurs in a flash, but the brain needs more time to create conscious impressions.

Masking Reality

Odd things can happen when stimuli follow in rapid succession, and it doesn't matter whether they are visual, acoustic or tactile. For example, registering one image can distort previous or subsequent images or suppress them completely if they are flashed quickly on a monitor. Psychologists refer to this effect as masking.

Masking makes it clear that our perception can deviate significantly from reality. Such systematic distortions of perception teach researchers the rules that the mind uses to construct its view of the world. The most frequently used technique is backward masking, in which the mask follows an initial stimulus. Here both stimuli can fuse completely, as neuropsychologist Robert Efron of the University of California at Davis found out. When Efron flashed a 10-millisecond-long green light immediately after a 10-millisecond-long red light, his subjects reported a single flash. What color did they see? Yellow, rather than a red light that changed into green. Two images in rapid succession sometimes result in a single conscious impression.

Recently Stanislas Dehaene, a cognition researcher at INSERM in Orsay, France, used the masking technique to study word processing. Dehaene presented subjects who were lying in a functional magnetic resonance imaging (fMRI) scanner with a series of slides in rapid succession. On the slides were simple words like "lion." These words appeared for barely 30 milliseconds—just long enough for the individuals to decode them correctly. Yet if a series of random images appeared before and after the target word, recognition fell off dramatically.

When the word was seen, the fMRI machine recorded vigorous brain activity in multiple locations, including in vision and speech centers. Masked, however, by the random images immediately preceding and following the word "lion" on the screen, brain activity was muted and confined to parts of the visual cortex involved in early phases of vision. Masking eliminated conscious recognition of "lion"; only the input stages of the visual brain were activated.

Researchers have prolonged the interval between stimuli and still achieved masking—up to

Our perceptions lag behind reality, casting doubt on our presumed unity of consciousness.

(The Author)

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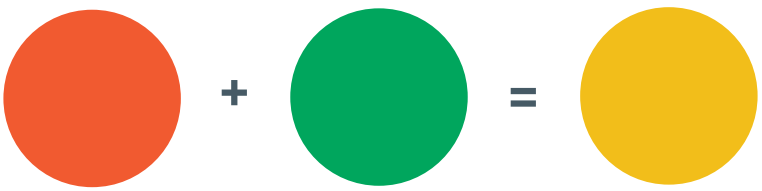
100 milliseconds. This means that even an image that strikes the retina one tenth of a second after a prior image can cancel out conscious perception of the first image. And yet, although the masking thwarts the development of a visual impression, it cannot prevent unconscious processing: test subjects who were encouraged to guess often correctly identified the initial images, even though they had been masked from conscious perception.

How Long Is a Moment?

How can we explain such aberrations? How is it even possible for a second stimulus to alter the perception of one that has already arrived? Think of two waves approaching a beach; if they move at the same speed, the second one should never be able to catch up with the first. But feedback mechanisms are involved in neural processing. As soon as neuronal signals within the visual cortex or even between the cortex and deeper brain regions start shuttling back and forth, as they do, subsequent information can distort the processing of earlier information.



When a short red flash is immediately followed by a short green flash, the brain does not see either color—only a single yellow image. This interference shows that our perception can deviate significantly from reality.

How far back in time masking can extend tells us something about temporal delay in the brain's feedback loops. If we add the experimentally derived maximum masking span of approximately 100 milliseconds to the 150 milliseconds that are required to discern a visual signal, this means that a minimum of about a quarter of a second is needed to consciously see a stimulus. Depending on its characteristics, the time span can be even longer but hardly ever shorter. Our perceptions, it seems, lag considerably behind reality—and we don't notice that.

Neuronal correlates of consciousness have a kind of minimum life span, and this existence corresponds in our experience more or less to what can be called the minimal perceptual moment. In all probability, subsequent brain activity during backward masking disturbs precisely those processes that signal the onset and disappearance of a target stimulus. Looked at the other way around, remnants of previous activity remain for a short time and may momentarily prevent the development of new NCCs. This competition among overlapping neural coalitions may be a significant feature of consciousness.

Sensory impressions come and go for various reasons: eye movements, a change in attention, or simply sensory cells becoming fatigued. With increasing visual input, for example, the firing activity of the visual cortex rises steadily and may shoot up precipitously once a certain threshold has been reached. This is why, for example, a light that is flashed briefly appears to be brighter than a steady beam of the same intensity. After the initial rapid increase, the perceived brightness of the steady beam gradually begins to drift to a lower value.

If sensing such a simple input can be so variable, imagine how complicated it must be for the brain to assess the actual world. One of the significant issues facing consciousness research is the fact that the world around us is so incredibly complex and multifaceted. Objects can only rarely be reduced to qualities that are as easily measured as simple brightness or color. A face, for example, is characterized by unique shapes, contours, colors and textures. The position and gaze of the eyes, the play of the mouth, the form of the nose, skin folds and blemishes—how do we integrate all these details into a unified image that conveys a person's identity, gender and emotional state?

This question goes to the core of the so-called binding problem. If NCCs arise within the various processing centers in the brain at different times, shouldn't each of the attributes be perceived with a time lag? How is the brain able to integrate all these individual activities?

Neurobiologist Semir Zeki of University College London has been researching this problem for many years. By measuring how subjects perceive squares that can randomly change color as they move on a screen, he has shown that a change in color of such an object is seen 60 to 80 milliseconds faster than a change in the direction of that object's movement. That is, one attribute is registered at a different time than another attribute of the same moment. This finding suggests that there may not be much truth to the presumed unity of consciousness—at least not when we are looking at extremely short time spans.

Such discrepancies rarely make themselves felt in our everyday lives, however. When a car races past me, its form does not seem to lag behind its color, even though each processing step—awareness of form, color, sound, speed and direction of movement—requires separate assessments by different regions of my brain, each with its own dynamic and delay. A unified impression is rapidly reached because the brain has no mechanism for registering the asynchrony. We are almost never

aware of the differing time lags. We simply perceive all the qualities of an object simultaneously—as incoherent as that composite image might be.

Snapshots in Time

A common metaphor for consciousness is that we live and experience things in a river of time. This implies that perception proceeds smoothly from our first waking moment of the day until we sink our heads onto the pillow at night. But this continuity of consciousness may be yet another illusion. Consider patients who experience "cinematographic vision" resulting from severe migraine headaches. According to Oliver Sacks, the neurologist and noted author who coined the term, these men and women occasionally lose their sense of visual continuity and instead see a flickering series of still images. The images do not overlap or seem superimposed; they just last too long, like a movie that has been stuck on freeze-frame and then suddenly jumps ahead to catch up to a real-time moving scene.

Sacks describes one woman on a hospital ward who had started to run water into a tub for a bath. She stepped up to the tub when the water had risen to an inch deep and then stood there, transfixed by the spigot, while the tub filled to overflowing, running onto the floor. Sacks came upon her, touched her, and she suddenly saw the overflow. She told him later that the image in her mind was of the water coming from the faucet into the inch of water and that no further visual change had occurred until he had touched her. Sacks himself has experienced cinematographic vision following the drinking of sakau, a popular intoxicant in Micronesia, describing a swaying palm as "a succession of stills, like a film run too slow, its continuity no longer maintained."

These clinical observations demonstrate that under normal circumstances, temporal splitting of sensations is barely, if ever, noticeable to us. Our perception seems to be the result of a sequence of individual snapshots, a sequence of moments, like individual, discrete movie frames that, when quickly scrolling past us, we experience as continuous motion. The important point is that we experience events that occur more or less at the same moment as synchronous. And events that reach us sequentially are perceived in that order.

Depending on the study, the duration of such snapshots is between 20 and 200 milliseconds. We do not know yet whether this discrepancy reflects the crudeness of our instruments or some fundamental quality of neurons. Still, such discrete perceptual snapshots may explain the common observation that time sometimes seems to pass more slowly or quickly.

PIER Getty Images

As soon as signals are received in the visual cortex, they are shuttled back and forth between groups of neurons, creating feedback that allows later information to distort the processing of earlier information.

Assume that the snapshot of each moment increases in duration for some reason, so that fewer snapshots are taken per second. In this case, an external event would appear shorter and time would seem to race by. But if the individual images were shorter in duration—there were more of them per unit of time—then time would appear to pass more slowly.

People who have been in automobile accidents, natural catastrophes and other traumatic events often report that at the height of the drama, everything seemed to go in slow motion. At present, we know little about how the brain mediates our sense of time.

If, in fact, changing coalitions of larger neuron groups are the neuronal correlates of consciousness, our state-of-the-art research techniques are inadequate to follow this process. Our methods either cover large regions of the brain at a crude temporal resolution (such as fMRI, which tracks sluggish power consumption at timescales of seconds), or we register precisely (within one thousandth of a second) the firing rate of one or a handful of neurons out of billions (microelectrode recording). We need fine-grained instruments that cover all of the brain to get a picture of how widely scattered groups of thousands of neurons work together. Eventually this level of interrogation may enable us to manipulate our flow of consciousness with technology. As things stand now, this is only a dream. M

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IMAGE SOURCE/AGE FOTOSTOCK

The guidelines judges and psychologists use to decide child custody cases have little basis in science. The system must be rebuilt on better research

CUSTODY DISPUTED

Courts are overwhelmed with couples who are splitting up and disputing custody of their children. If parents cannot agree on their children's fates, a judge will decide who gets custody, and increasingly, psychologists are becoming involved as expert evaluators during legal wranglings. But do any of these professionals have proof that the bases for their life-determining decisions are empirically sound? It seems not, and it is the boys and girls who suffer.

Parents often think that judges possess some special wisdom that will allow them to determine a custody arrangement that is somehow better than what parents can devise themselves. They don't. Although the details vary, every state's law indicates that custody decisions are to be made according to the "best interests of the child." That rule of thumb sounds laudable, but it is so vague that the outcome of every case is unpredictable. The possibility of "winning" in court, paired with the emotional dynamics of divorce, encourages parents to enter into custody disputes, which only increases conflict between them—and conflict is a major cause of lasting psychological damage to children of separating spouses.

Furthermore, custody evaluators oftentimes administer to parents and children an array of tests to assess which custody arrangement

By Robert E. Emery, Randy K. Otto and William O'Donohue

Court tests that expert evaluators use to gauge the supposed best interests of a child should be abandoned.

might be best. Given the frequency, high cost and social importance of custody evaluations, we might expect to find a large body of research on the tests' scientific validity. Yet only a few studies have been completed; more are needed, but the few do show that the tests are deeply flawed. Our own thorough evaluation of tests that purport to pick the "best parent," the "best interests of the child" or the "best custody arrangement" reveals that they are wholly inadequate. No studies examining their effectiveness have ever been published in a peer-reviewed journal. Because there is simply no psychological science to support them, the tests should not be used. And other, more general psychological tests that evaluators sometimes employ, such as IQ tests, have little or no relevance to custody decision making and should be dropped as well.

(The Authors)

Psychologists ROBERT E. EMERY, RANDY K. OTTO and WILLIAM O'DONOHUE collaborated on a white paper about custody disputes, to be released in late 2005 by *Psychological Science in the Public Interest*. Emery teaches at the University of Virginia, Otto at the University of South Florida and O'Donohue at the University of Nevada at Reno.

Conflict, the Real Barometer

There is, however, one tremendously important conclusion about separation that has been proved by extensive, sophisticated, multidisciplinary research: the level of conflict between parents that children experience during separation, and the ongoing disagreements they may be exposed to thereafter, greatly influences the degree of psychological trouble the youngsters will have in the short and long term.

Research shows that most children are resilient despite a divorce, and it is quite possible for them to suffer no greater incidence of psychological maladjustment than kids whose conflicted parents remain married. Studies tell us that many of the problems observed among youths from divorced families are actually present before the separation. Parental fighting often precedes a separation or divorce, and various analyses demonstrate that children fare better psychologically if they live in a harmonious divorced family than in a conflict-ridden two-parent household.

The bottom line is that in any family situation, children do better if adult clashing is minimal or at least contained so children do not witness or become involved in it. The process of dissolution, and the nature of ongoing family relationships, is more important to a child's mental health than the structure of any particular arrangement, whether that be sole custody, joint physical custody, or liberal or limited visitation with the noncustodial parent. Researchers report that both boys and girls function equally well living primarily with either their mother or father. Other important factors in minimizing the trauma for offspring include having a good relationship with an authoritative resident parent (one who is loving but firm with discipline), economic security and a good relationship with an authoritative nonresident parent.

The coupling of the vague "best interests of the child" standard with the American adversarial justice system puts judges in the position of trying to perform an impossible task: making decisions that are best for children using a procedure that is not. We appreciate the terrible dilemma that the best-interests standard creates for judges, custody evaluators and, of course, parents and children. We also believe that a mental health professional may be in a better position to make sound recommendations about custody than a judge bound by rules of legal procedure. Nevertheless, we believe it is legally, morally and scientifically wrong to make custody evaluators de facto decision makers, which they often are

BILL FRITSCH age fotostock

because judges typically accept an evaluator's recommendation.

Encourage Parents to Decide

Some straightforward policy changes would improve custody decisions. First, we urge judges, lawyers and other advisers to encourage parents to reach custody agreements on their own through divorce mediation, collaborative law, good-faith attorney negotiations or psychological counseling. Studies show that these efforts reduce conflict and encourage more cooperative, ongoing interactions between parents. Such arrangements facilitate positive relationships between children and their mothers and fathers. These practices also embrace the philosophy that, in the absence of abuse or neglect, parents should determine their own children's best interests after separation, just as they do when they are married or living together. Parents—not judges or mental health professionals—are the best experts on their own children.

One important reason to follow this approach from the outset is that parents ultimately must manage their own relationship and custody decisions. A cooperative approach, rather than adversarial litigation, will help achieve this outcome. Options include pro se divorce, in which parents manage legal matters without lawyers; divorce education, usually involving court-mandated classes on parenting; cooperative negotiations between parents and attorneys (including a new approach called collaborative law whereby lawyers agree not to go to court); family therapy; and the most firmly established of the options, divorce mediation, in which parents negotiate a settlement with the help of a neutral expert, usually a mental health professional or an attorney.

The second step for reducing conflict is for state legislatures to enact clearer guidelines for determining custody when parents cannot reach an agreement. A fair but less vague standard would reduce the number of contested cases that are brought to court in the first place. Too often one or both former partners seek litigation precisely because the best-interests approach encourages false hopes of "winning." Firmer rules would discourage litigation and reduce conflict between parents—the ultimate goal. We find particular merit in the proposed "approximation rule"—the suggestion that postdivorce arrangements should approximate parenting involvement in marriage. The most important advantage of this guideline is that parents and their attorneys would know what to expect of the courts, and this knowledge would promote earlier settlement.

No state has yet implemented the rule, so we have no evidence of its effectiveness; however, the American Law Institute, whose model statutes often become the basis for state laws, has endorsed the idea in its proposed reforms of divorce and custody law.

Finally, we recommend that custody evaluators offer only opinions that are clearly supported by psychological science. Until far stronger scientific support arises, this recommendation means that evaluators should abandon the use of all custody "tests" that purport to measure children's best interests directly or indirectly.

Our recommendation to limit expert testimony may seem radical, but we are simply urging the same rigor that is applied to expert testimony in all other legal proceedings. The American Psychological Association, the Association of Family and Conciliation Courts, and the American Academy of Child and Adolescent Psychiatry all have developed guidelines for professionals who conduct custody evaluations. Each group recommends an assessment of children's needs, parents' abilities to meet these needs, and parents' abilities to provide for future needs. Still, there is little agreement about how to assess these factors. We therefore urge professional organizations to develop clearer guidelines on which tests have a basis in science and to generate data on the appropriate inferences that can be drawn from responses children and parents provide in taking those tests. M

> Parents should determine their children's lives after separation, just as when they are married.

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Mending the SPINAL CORD

Researchers are finding ways to help nerves regenerate, and hope for therapies is growing

By Ulrich Kraft

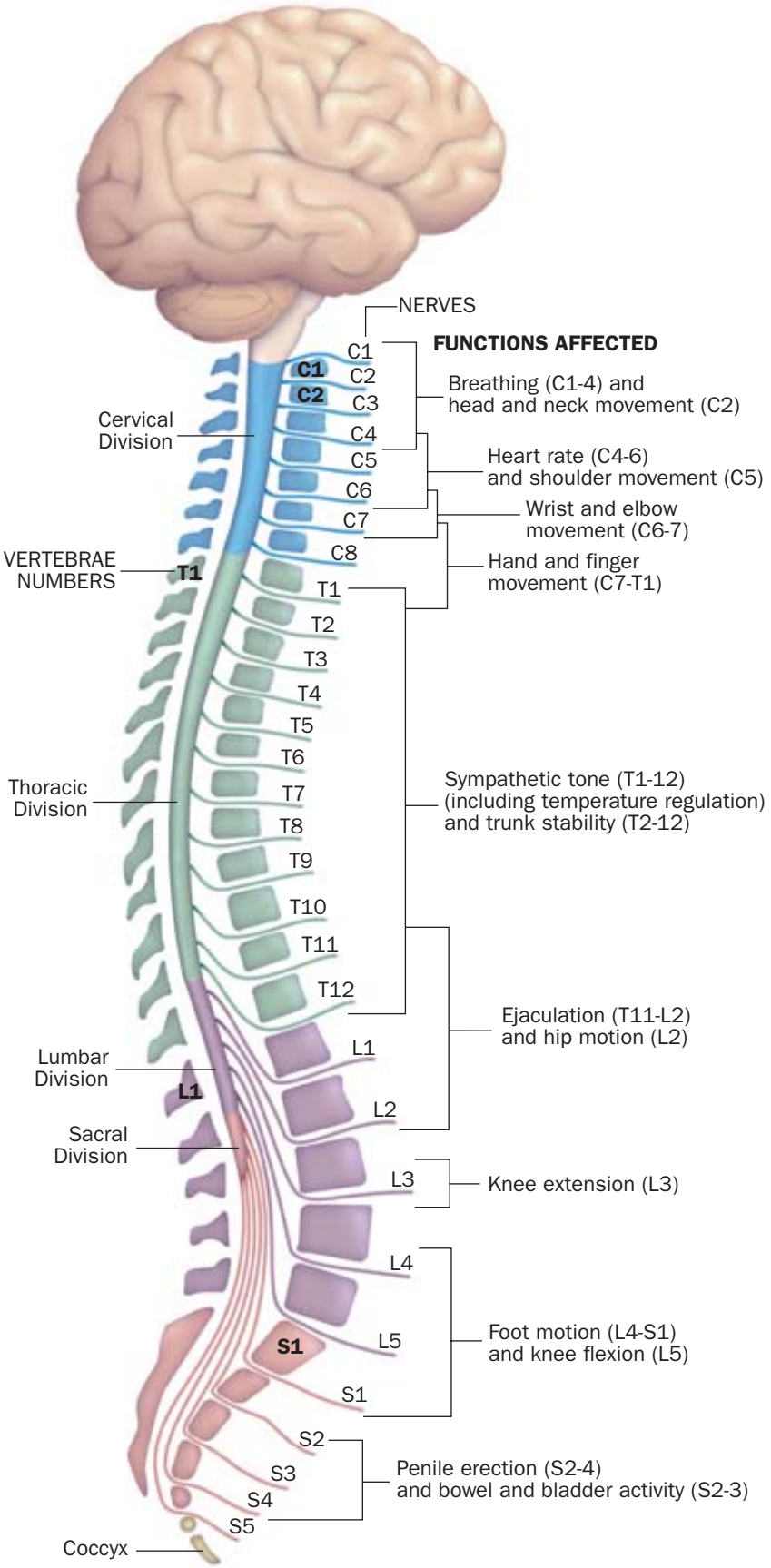
REZA ESTAKHRIAN Getty Images

Many people are familiar with the story of Christopher Reeve, the actor who played Superman in the blockbuster movie of the same name. In May 1995, while riding in an equestrian competition, Reeve was thrown off his horse, severely damaging his spinal cord when he hit the ground.

In an instant, Reeve became a quadriplegic—paralyzed from the neck down. He was confined to a wheelchair and could not even breathe without a machine. Nevertheless, for nine years—until he died in October 2004—he championed the call for more research into spinal cord repair. Despite his efforts, progress was slow.

The need for advances is greater than most people realize. In the U.S., 11,000 individuals are paralyzed every year. There are now more than 200,000 Americans with spinal cord damage, a number that, ironically, has grown

Spinal Cord Responsibilities



because of improved acute care in the hours immediately following injuries; people who once would have died from traumatic damage now survive. Some 60 percent of victims are male, 60 percent are hurt in motor vehicle accidents or athletics, and more than 40 percent are younger than 30 years. All face a lifetime with little prospect of regaining any function, and many die prematurely from complications such as organ degeneration and infection.

Finally, however, science offers glimmers of hope that nerve cells in the spinal cord and brain could someday regenerate. In several studies, rats with injured spinal cords have recovered some movement, a few even walking again. Monkeys have bounced back, too. Experts now say that even human nerves are fundamentally repairable. This news has aroused great optimism among patients and scientists, but knowledge about how regeneration happens and how those mechanisms could be turned into reliable therapies is only beginning to become clear.

Prevent the Barrier

The spinal cord, about as thick as your finger, contains millions of nerve fibers that drive a vast array of bodily functions, including muscle control and sensory processing. Injuries do not just paralyze arms and legs; victims lose control of their bladder and bowels, cease to feel skin pain and lose sexual function. For many paraplegics, being able to feel things again is almost as important as being able to walk.

It had been considered absolute truth that in the brain and spinal cord—collectively known as the central nervous system (CNS)—neurons do not regenerate. This phenomenon frustrated neuroscientists because severed nerves in other parts of the body can reestablish connections. In recent years, however, improved medical technology has shown that after a spinal cord is cut, nerve cells do begin to extend new fingers, called axons, which could carry signals across the gap. Almost immediately, however, a protein latches onto neurons trying to grow and ultimately shuts the process down. Scientists have dubbed the protein Nogo.

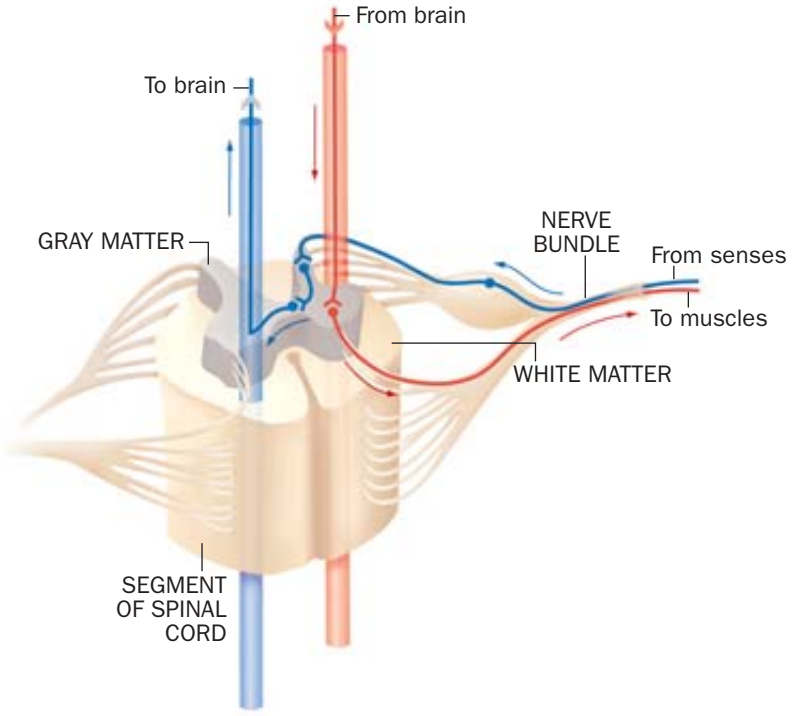
Nogo was found in the brain as well and more recently in some parts of the peripheral nervous system. Experts theorized that this molecular brake prevents uncontrolled nerve cell growth once the CNS is mature, as a way of stabilizing the complex network.

Researchers still had to prove Nogo's culpability. One of the leaders in this effort was Martin

MELISSA THOMAS

Trunk Line

Butterfly-shaped spinal cord conveys impulses from our senses to the brain (*blue*) and instructions back to muscles and organs (*red*). The inner core, or gray matter, consists mostly of neuron cell bodies. The outer white matter consists primarily of axons—the long signal-carrying arms of those neurons.



E. Schwab, head of neuromorphology at the Brain Research Institute at the University of Zurich. In the mid-1990s Schwab developed an antibody that would bind to Nogo so it could not latch onto the neurons and stop axon growth. Schwab partially severed the spinal cords of several rats. He then implanted a pump underneath the skin that steadily infused the antibodies into the damage site for a few weeks. Microscopic imaging showed that a thin spindle of nerve tissue was bridging the gap at the injured spot. Behavioral tests indicated that the rats moved similarly to others that did not have any spinal cord damage. "They swim, balance atop poles, reach out for food and climb up ropes," Schwab says.

In 2000 independent research groups simultaneously announced that they had found the gene that prompts the production of human Nogo. By cloning this DNA, they were able to produce antibodies to it. Major pharmaceutical firms took notice; GlaxoSmithKline participated in one discovery group, and in 2001 Novartis secured the rights to Schwab's antibody formulation.

Some scientists were skeptical that the drug industry was truly interested in helping paraplegics, however. An article in *Science* noted that there were far too few patients—too small a market—for firms to justify the enormous expense of developing a commercial drug. The journal maintained that companies were interested in Nogo antibodies to potentially treat neurological conditions that afflict large numbers of people, such as stroke or Parkinson's disease, which involve a massive die-off of CNS neurons.

Block the Dock

Other scientists were looking for alternative solutions. Rather than trying to handcuff Nogo, neurobiologist Stephen M. Strittmatter of Yale University looked for a way to block the port, or receptor, on nerve cells where Nogo docked. In 2001 he identified the receptor and the shape of the nub on a Nogo molecule that allows it to dock there. The nub, or fragment, was a peptide molecule, which Strittmatter managed to synthesize artificially. The goal was to seal off the receptors by filling them with the synthesized peptide.

To test the approach, Strittmatter administered the peptide to spinal cord injuries in rats for four weeks, through a catheter inserted into the animals' spines. A number of nerve fibers did grow back, and the rats were able to walk better than without the treatment, according to Strittmatter.

The next stage of work will be to investigate whether such compounds are safe and effective in humans. The dock stopper may possess one advantage: Strittmatter and others have recently found evidence that proteins other than Nogo dock in the Nogo receptor and thwart axon growth; crippling Nogo alone, therefore, may not leave axons free to

(The Author)

ULRICH KRAFT is an editor at *Gehirn & Geist*.

MELISSA THOMAS

For nine years as a quadriplegic, actor Christopher Reeve, who played Superman, championed the call for more research. Public attention may have waned since his death in October 2004.

J. SCOTT APPLEWHITE *AP Photo*

regenerate. One suspected protein is myelin-associated glycoprotein, found in the sheath of myelin that insulates axons. Another is oligodendrocyte myelin glycoprotein. Hindering the Nogo receptor could stop all three—at least in theory.

Limiting Damage

Agents such as Nogo are not the only factors preventing a severed spinal cord from knitting back together. Regeneration is also frustrated by the body's otherwise helpful efforts to protect the wound site. Severed or crushed nerves evoke a massive inflammatory reaction. It causes fluid to fill the gap and bloat surrounding tissue, cutting off blood supply to intact neurons around the injured cells, crushing the nerve cells with pressure, and releasing various messenger molecules that prompt cell death among the neurons. The end result is that the nerve gap is enlarged. Scar tissue then begins to form to seal the wound. The scar tissue—made of dense, chainlike molecules—presents an impenetrable barrier to new axon growth.

Elizabeth Bradbury of King's College London may have found a way to clear this thicket with a molecular machete called chondroitinase ABC. This bacterial enzyme removes the sugars from proteoglycans, dissolving them. Bradbury partially severed the spinal cords of rats and then immediately treated the injured areas with chondroitinase ABC. The substance did its job. Through a microscope, she could see that nerve cells at the injury site were making new connections. Two weeks later the treated rats were walking almost as well as the uninjured control group. The untreated rats failed miserably.

To improve delivery of such agents, Dennis J. Stelzner of the State University of New York Upstate Medical University has packaged the enzyme in biodegradable nanospheres and injected them into the injury site. As he explained at the Society for Neuroscience's annual meeting in October 2004, the nanospheres degraded over time, gradually releasing their contents. This means that only a single injection might be needed to treat a wound, rather than multiple injections, each one bearing a danger of further injury and infection.

Piercing the Scar

Scar tissue problems could perhaps be overcome in another way as well. Back in 1985, Geoffrey Raisman, now at University College London, discovered a unique trait of the olfactory system (sense of smell). Unlike other nerve cells, most olfactory neurons can regenerate spontaneously when damaged—such as when we have a cold or sniff a strong solvent. Raisman found that newly sprouting nerve fibers are surrounded by olfactory ensheathing cells (OECs), specialized cells found nowhere else in the body. In time, Raisman's team managed to cultivate OECs from rats and transplant them at the injury site in rats whose spinal cords had been partially severed.

Through a microscope, Raisman could see that the OECs lined up tightly, creating a bridge between the two ends of cut spinal nerves. New axons began to grow along this scaffolding until they had traversed the gap. Insulating myelin sheath also began to form along the fresh nerves. As a result, the rodents were once again able to use their forefeet to grasp food and undertake complex motor activities such as climbing. In follow-up experiments, Raisman showed that the therapy could be successful even when applied two or three months after an injury. Several labs are now working with olfactory ensheathing cells.

Other kinds of repair could help restore certain bodily functions, such as control over the bladder and bowels. More than half of spinal cord injuries are partial; many nerve fibers remain more or less intact, but because of injury trauma and inflammation they have lost their myelin sheaths. Without the insulating layer the nerves no longer conduct electrical signals properly.

Cells called oligodendrocytes are responsible for producing myelin in the CNS. Neurobiologist Hans Keirstead of the University of California at Irvine is now trying to coax them to restore the insulation in damage sites. One controversial tool is the embryonic stem cell, which can develop into virtually any type of cell in the human body. Keirstead is using special culturing techniques to turn them into the precursors of oligodendrocytes, known as oligodendrocyte progenitor cells. In early tests, injecting these cells into the spinal cords of rats seven days after damage led to partially restored motor function eight weeks later. The rodents "were not playing soccer," Keirstead noted at the October 2004 neuroscience meeting, "but they were doing extremely well."

Trying a treatment too soon not only raises false hopes, it can cause phantom pain.

False Hopes

Another group of rats that did not receive the progenitor cells until 10 months after their injuries experienced no recovery. Keirstead theorizes that scar tissue prevented remyelinization. It is possible that a combination therapy employing olfactory ensheathing cells in addition to progenitor cells might work.

When such ideas are mentioned, however, Schwab of Zurich notes that other investigators who have tried to combine different healing schemes have had discouraging results. Even in animal tests, combination therapies proved to be extremely complex, he says.

This bare fact highlights a disturbing facet of spinal cord research: much of it is being conducted under a spotlight of publicity, which may influence scientists to prematurely try unproved therapies on humans. "For the past 30 years there have been questionable experiments on paraplegics," Schwab maintains. In most cases, he adds, "the scientific foundations were rudimentary." Trying a treatment too soon not only raises false hopes, it can cause phantom pain from new nerve pathways that make improper connections.

Schwab insists that investigators follow the tried-and-true routine for medical experimentation: first test in lab cell cultures, next in rodents, then in primates and only then—with knowledge of benefits and side effects—in humans. Others add the warning that success in rodents may not lead to success in people; the species differ dramatically in everything from the size of their spinal cords to the way in which they walk. Testing on primates such as apes, which are much more similar to *Homo sapiens* than rats are, is controversial, however. For example, cuts into primate spinal cords must be made that may leave the animals paralyzed should trial treatments fail.

Yet no leap to humans can be made without this kind of intermediate step. Schwab's latest research may serve as a model. Following his promising tests of Nogo antibodies in rats, he moved on to rhesus monkeys. Deep cuts into their backbones caused the animals to be paralyzed on one side, and they could scarcely use one hand. Within seven weeks of treatment, they had regained a significant amount of dexterity. "They opened drawers, they grabbed food—almost like healthy monkeys," Schwab notes.

Because the monkeys showed no side effects, Schwab will now test Nogo antibodies on numerous paraplegic people in scattered research centers, in part so other scientists can oversee the results. Schwab does not expect miracles, and he would be overjoyed even to restore key functions such as bladder control and sexual function, for which only a small number of reconnected nerve pathways are needed.

Such simple progress is all that paralyzed people anticipate, as evidenced in letters and e-mails they send to Schwab's office. He does not see much disappointment in them when he explains the hard truth about modest, if any, possibilities for improvement in a given experiment. He says the patients are not expecting wonders, because they are aware that the situation is complex. "But after so many years of silence, most of them are glad to know that today there is serious work on therapies. As for concrete results, they tend to think of the next generation." M

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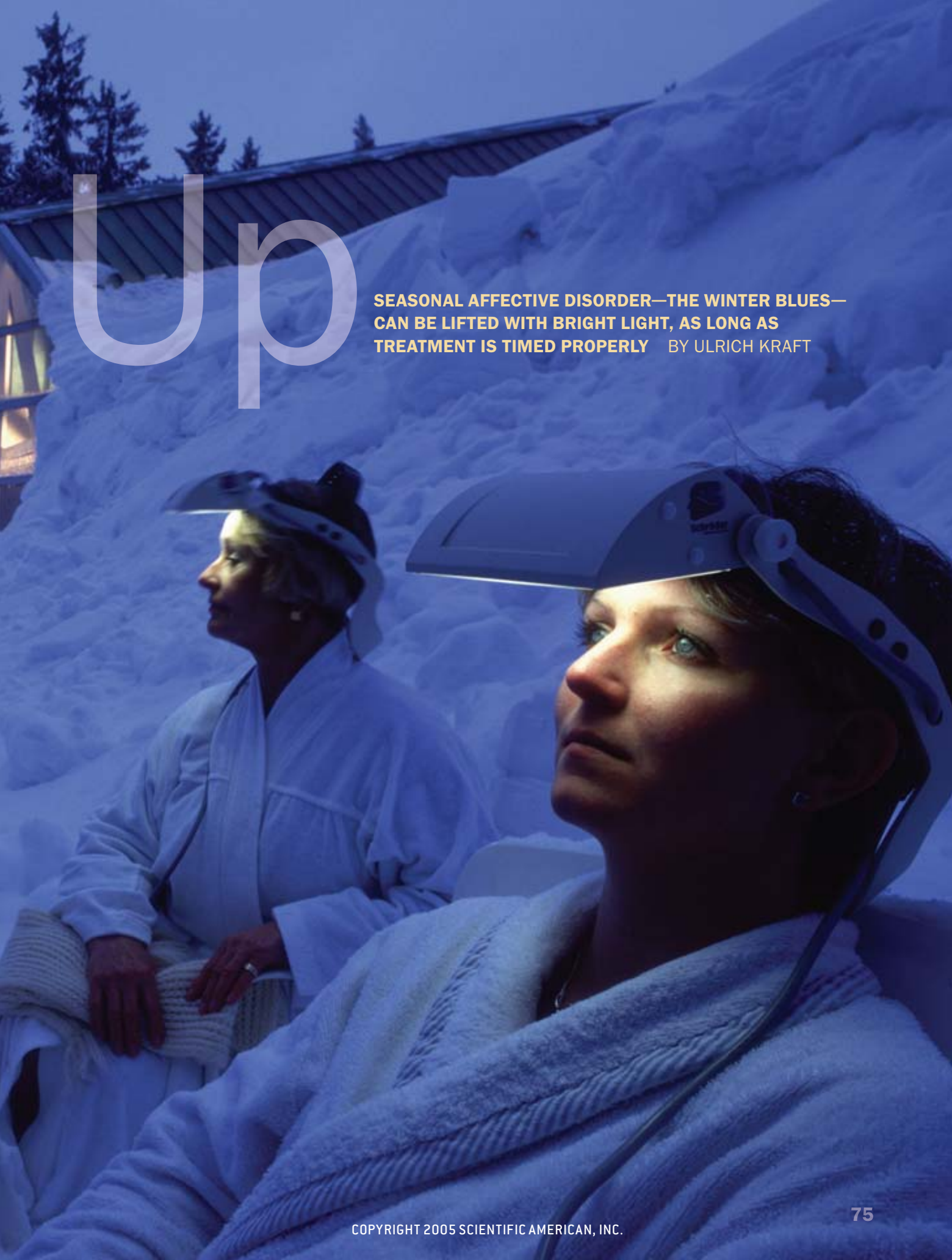
Lighten



Up

SEASONAL AFFECTIVE DISORDER—THE WINTER BLUES—CAN BE LIFTED WITH BRIGHT LIGHT, AS LONG AS TREATMENT IS TIMED PROPERLY BY ULRICH KRAFT

Autumn. Mornings are dark. Dusk comes disheartening early. You are feeling more tired, melancholy. The rapidly disappearing daylight seems almost to drag away part of your spirit with it. Should this dip in humor worry you? Not really—you'll adjust. Unless you are prone to seasonal affective disorder. For the several million Americans who succumb, the darker half of the year brings a heavy veil of sadness. They become depressed, listless, chronically fatigued, and their mood does not rebound until March, when the daylight extends to early evening.

In general, the farther north one lives on the globe the more common seasonal depression becomes. Below the 30th parallel, which links Jacksonville, Fla., to Houston and the Baja Peninsula south of San Diego, the winter blues are virtually unknown. In sunny Florida, just 1 percent of the population suffers from seasonal affective disorder, appropriately known as SAD, but in New York State the rate is 5 percent. In Alaska, one out of every 10 residents experiences winter mood problems.

Why are some people bowled over, whereas their neighbors simply feel a bit glum? And how can all of us brighten our autumnal outlook? Psychologists and neuroscientists are finding answers. And what they are discovering goes far beyond antidotes for seasonal depression; they are gaining insight into how our environments influence our minds, how our brains control mood and how our internal clocks keep many bodily functions in sync.

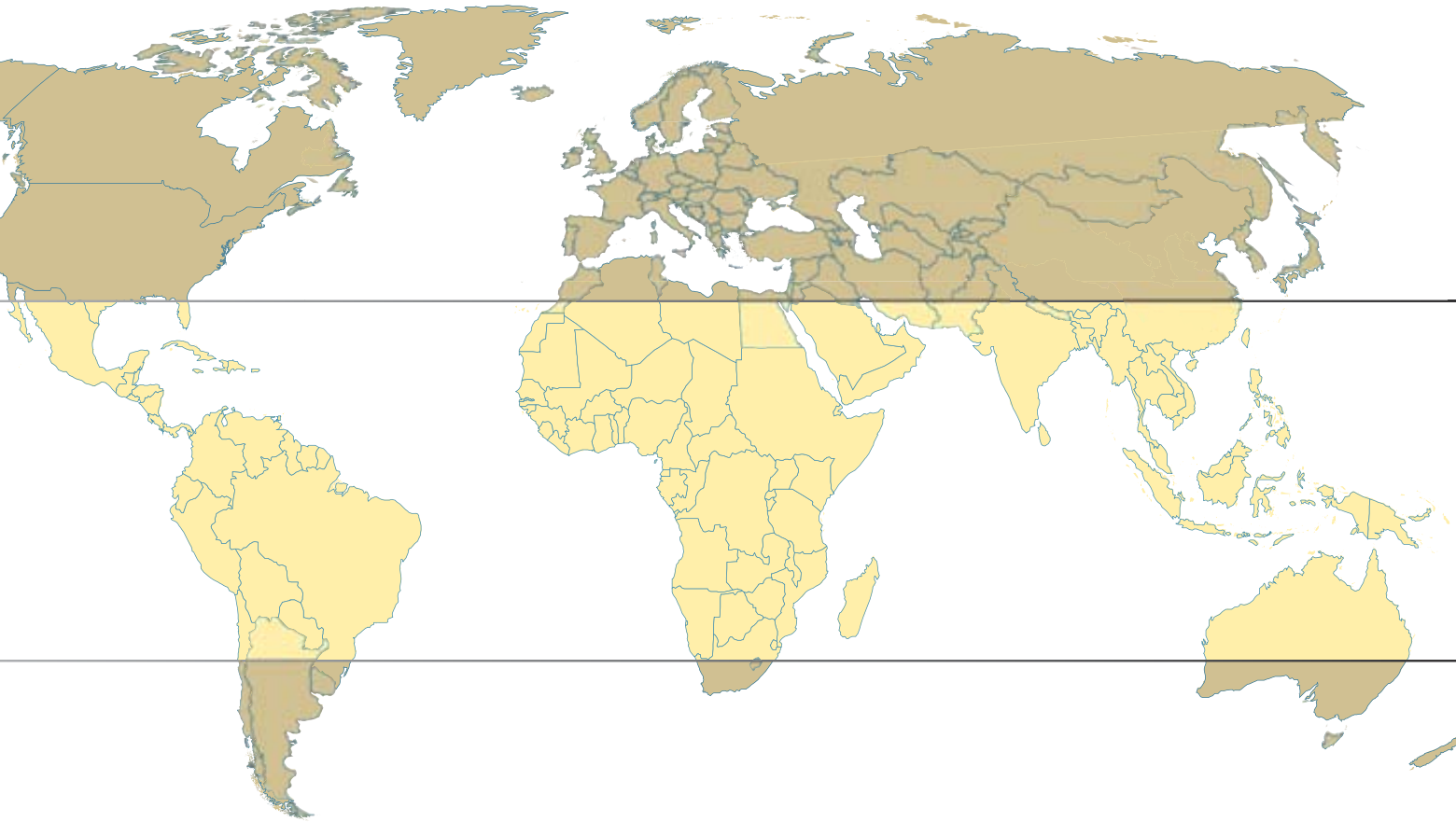
Sad yet Hungry

Seasonal depression has been recognized for millennia. The great Greek physician Hippocrates was aware in the fifth century B.C. that mood and energy varied with sunlight. People living in sunnier regions were happier, had a more optimistic outlook and were less often sick, he wrote in his treatise *Airs, Waters, Places*. Yet it was not until the middle of the 20th century that people began to pay real attention to the condition. And it was not until the 1980s that researchers began to examine winter depression closely. Norman E. Rosenthal and Thomas A. Wehr, then at the National Institute of Mental Health (NIMH), and their colleagues developed diagnostic criteria that allowed them to evaluate symptoms objectively. In 1984 the malady was finally christened seasonal affective disorder.

The classic signs include diminished pleasure in life, a gloomy mood and difficulty concentrating. In the morning, SAD sufferers say they feel "good enough," but their liveliness fades with the day's passage. Week by week, as the nights lengthen, these individuals withdraw from social life, lose interest in sex and muster little enthusiasm for anything. They describe themselves as empty.

All these symptoms are common to depression, too. The difference is the seasonal link. SAD

GINTER *Bilderberg/Aurora (preceding pages)*; SAMUEL VELASCO *(these two pages)*



Between the 30th parallels (*yellow area*), winter depression is almost unknown. Beyond them, rates of the ailment generally increase toward the poles—for example, from 1 percent in northern Florida to 10 percent in Alaska.

always commences at a particular time of year. "Some people have symptoms as early as September 1, but the problem is really significant in October and November," explains Siegfried Kasper, a psychiatrist at the Medical University of Vienna in Austria. In spring the problem disappears completely, as if it had never existed. Furthermore, whereas depressives often lie awake at night for hours, SAD people tend to sleep excessively, as much as four hours more a night than in summer. They seldom experience lack of appetite, common in depression, and often have hunger attacks that they satisfy with carbohydrates or sweets, leading to weight gain.

Hormone of the Night

The persistence of SAD is clear, but why would a simple absence of daylight trigger such emotional changes? Is the amount of sunlight even the critical factor? For SAD individuals, spending a long time in a windowless room can set off a depressive episode. The answer lies in how humans detect light. Many animals track the seasons by noting changes in day length. Bats, hamsters and groundhogs use the signal to go into hibernation. Daily and seasonal changes in daylight must somehow be registered by the eyes and calculated by the brain. In the early 1970s a small bundle of neurons was discovered that performed this analysis. The bundle—the size of a grain of rice—is the suprachiasmatic nucleus (SCN), and it is located in the brain's hypothalamus near where the two optic nerves from the eyes cross [*see illustration on page 79*].

The SCN is our body's master timekeeper, our internal 24-hour clock. If this pinch of cells is removed from rats, many processes driven by normal circadian rhythm collapse, including the animals' sleep-wake cycle as well as functions of their heart, intestines and liver. As soon as the first rays of sun at dawn sneak between the eyelids onto the retina, special photoreceptor cells signal the neurons of the SCN to begin firing more rapidly. The SCN maintains this rate all day, like a signaling beacon that doesn't stop. The "ringing"—via many intermediate steps—suppresses the secretion of melatonin, the so-called sleep hormone, by the pineal gland. An evening rise of melatonin in the bloodstream makes us sleepy, and high levels prevail all night long; during the day, however, the hormone can scarcely be detected.

Melatonin's ebb and flow repeats every day. But the cycle's precise timing and duration varies across the year. In spring and summer the SCN neurons fire for longer each day; shorter signaling occurs during autumn and winter. As a result, the profile of melatonin synthesis differs for each season, and it affects many aspects of animals' lives, among them appetite, total daily activity levels, social contact, drive to reproduce and, of course, the need for sleep.

Those daily and seasonal levels of melatonin

For SAD individuals, nightly melatonin production lasts too long, sapping their mood and sexual interest.

might hold the key to SAD, Thomas Wehr of the NIMH realized during his work in the 1980s. Wehr wondered whether the daily profile of melatonin production somehow differed for SAD sufferers. After tracking many subjects, Wehr found that the seasonal variation in melatonin secretion was similar for SAD and non-SAD people. But for SAD subjects the nightly melatonin cycle lasted 38 minutes longer in winter.

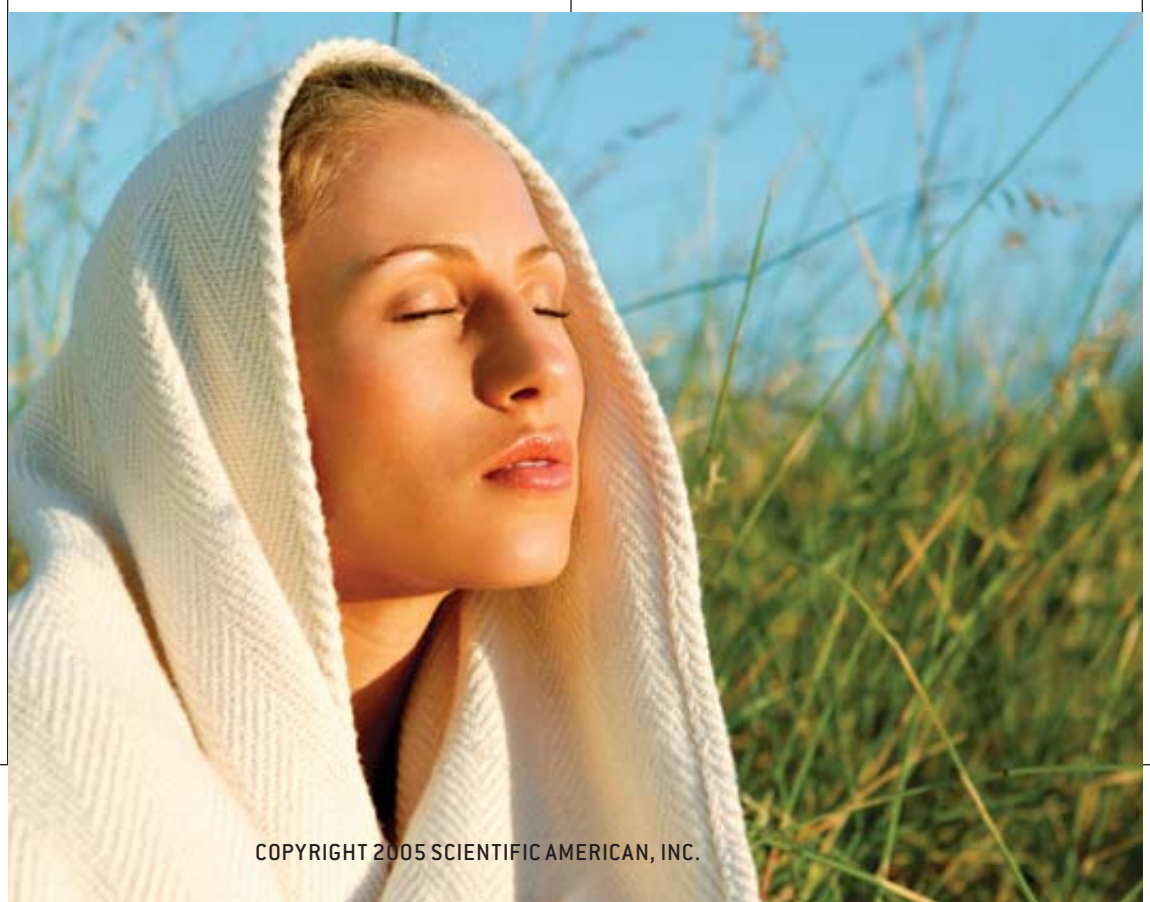
A 38-minute disparity might seem insignificant, given that daylight on a June day in the U.S. lasts nearly 16 hours and that even on a December day it ekes out a little more than eight hours. But the difference matters tremendously. In hamsters, for example, prolonging melatonin secretion by 30 minutes changes reproductive patterns.

Jet Lag Proves It

Scientists thought the extended melatonin dose was the answer to SAD—after all, as the days lengthen in spring, the melatonin-secretion phase shortens and humans revive their interest in life. But the explanation had a problem: there was no physiological evidence that an additional half an hour of melatonin caused depression. And pharmaceuticals that suppress synthesis of the hormone did not seem to help SAD patients.

Researchers concluded that something more basic must be amiss in how SAD people sense light. Led by Alfred Lewy, head of the Sleep and Mood Disorders Laboratory at the Oregon Health & Science University, scientists in the past decade have devised a more comprehensive theory. In today's world, lit by incandescent, fluorescent and halogen lamps day and night, people have become more or less decoupled from the natural daylight cycle. In the morning, most people's inner clocks seem to register artificial light as weaker than sunlight, yet the rays are still enough of a sign to suppress melatonin secretion. Man-made light also keeps the expected production of melatonin at bay after the sun goes down. As a result, our circadian clocks tick somewhat independently of actual day length and season.

Not so for people with seasonal affective disorder. For SAD patients, the 100 to 500 lux brightness of typical homes is not enough to tell the SCN to halt the pineal gland. In the morning, the gland continues to secrete melatonin—at lower levels than at night but still to a greater degree than the normal near-zero of daytime. And in the



The longer daylight hours of spring cause SAD to suddenly disappear, and it stays away until autumn.

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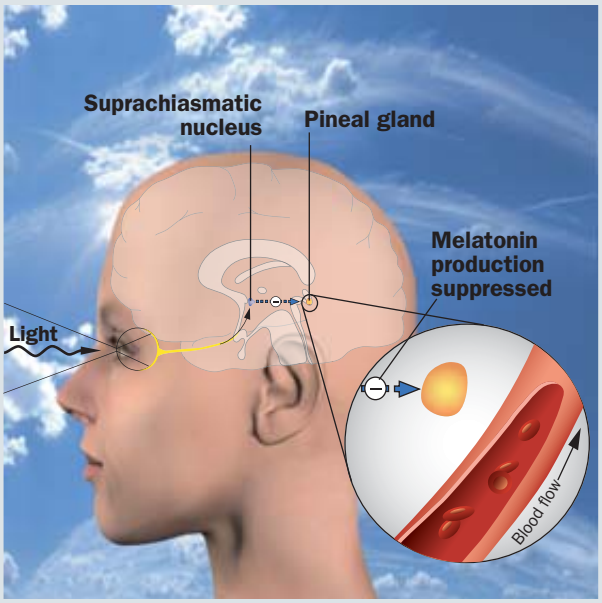
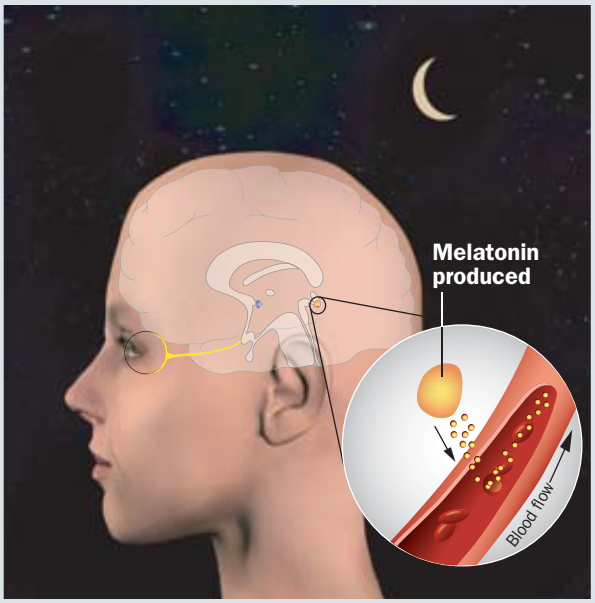
Melatonin Switch





The passing of daylight hours is detected by the eye's retina and transmitted to the suprachiasmatic nucleus (SCN). This bundle of neurons, about the size of a grain of rice, lies in the hypothalamus, near the point where the two optic nerves cross, and operates as our master clock. It controls daily body rhythms, such as the activity of organs and the sleep-wake cycle. During daytime, the SCN fires powerfully and—through intermediate chemical steps—suppresses the secretion of melatonin, the "sleep hormone," by the pineal gland (*left*). At night the SCN firing drops, and melatonin flows into the bloodstream, making us drowsy (*right*).

evening melatonin rises despite the artificial lights, dampening mood by dinnertime and increasing the likelihood of depression.

Further refinement of this theory has pointed to a phase delay in melatonin secretion as the real culprit. The internal clocks of SAD patients not only go into night mode earlier in the evening and remain in night mode longer in the morning, they lag behind natural daylight time and trail other body rhythms. That our brains cannot readily shrug off such phase shifts is clear to anyone who has ever made a long-distance flight. Immediately after such a trip most people are not just tired but also grumpy and listless—jet lag has them down. After a few days their inner clocks adjust their phase to the new timing of dawn and dusk, and the symptoms disappear. David Avery of the University of Washington, who has studied seasonal depression for years, explains the analogy: "People with seasonal depression experience something like constant jet lag. They wake up and feel as if it is the middle of the night. And as several studies have shown, from a physiological point of view it really is the middle of the night for them."

Morning Shower of Light

Knowing the physical cause of SAD has lent credence—and specificity—to one form of therapy that has been gaining in recent years, according to anecdotal reports. In Hippocrates' day the remedy of choice was to have sufferers look at the sun, a practice that was somewhat hard on the eyes. Today so-called light boxes do a better job. The boxes, one or two feet on a side, contain special lamps that produce up to 10,000 lux of white light—equivalent to the outdoor light of a bright summer day.

For many patients, 30 to 45 minutes of bright light every day, begun during the dim stretches of autumn and continued throughout winter, improve their mind-sets demonstrably. The timing of the dose is important, however. According to various studies, soaking up the light at noon is worthless, and evening doses are of limited value for

(The Author)

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Intensive light tells the brain's inner clock it is time to reverse the nocturnal slump.

improving patient moods. Early-morning applications are far and away the best. Patients must wake up early and sit directly in front of the boxes, typically while having coffee or looking at the day's newspaper. Apparently, the intensive light tells the timekeeping neurons in the suprachiasmatic nucleus that the day has begun, so it is time to end the nocturnal synthesis of melatonin. According to most reports, more than 60 percent of SAD patients respond to the morning showers of light.

Done every day, the regimen also appears to reset the clock so it is in proper phase again with the rest of the body. And that adjustment seems to correct the evening onset of melatonin secretion.

According to current treatment protocols, patients should be seated within one to two feet of the light boxes by 6 A.M. or so. Yet Michael Terman, a psychologist at Columbia University, says this strict regimen may have to be adjusted. "For some people, that time is much too early. What's important is not the time of day but the 'time' on each patient's circadian clock—where the person is in his or her daily cycle of melatonin production." By taking blood samples to determine melatonin levels, Terman has found the most effective timing of light treatment for dozens of patients. They seem to benefit most when they sit in front of the lamps about eight hours after their bodies start producing the hormone the evening before.

More Serotonin, Please

More recently, one of the brain's chemical messengers has been implicated as a co-conspirator in the wintertime blues: serotonin. This neurotransmitter affects various aspects of appetite, sleep and, most important, mood. Serotonin plays a decisive role in many types of depression, and increasingly, depressed patients are being treated with drugs that delay the reuptake of serotonin, keeping levels in the blood higher. It turns out that these so-called SSRIs—selective serotonin reuptake inhibitors—also help people with seasonal mood swings.

This correlation suggests that as autumn daylight diminishes, the serotonin levels in SAD sufferers change inappropriately. Various studies have since revealed that most people's serotonin levels reach an annual low point during January and rise with the longer days of spring. But new thinking suggests that falling serotonin levels could conspire to make certain individuals depressed if they have one kind of genetic makeup.

Just like every other gene in our bodies, two copies of the so-called *5-HTTLPR* gene exist in-

NAJLAH FEANNY *Corbis*

SAD sufferers can brighten their mood by sitting early each morning directly in front of special light boxes that simulate strong natural sunlight.

From Bulimia to Jet Lag

Light therapy has succeeded in fending off seasonal affective disorder—and with virtually no side effects. Though not a miracle cure, it is helping people overcome other challenging conditions:

Bulimia. This binge-eating disorder, which primarily afflicts young women, is associated with serious psychological maladies. But psychologist Raymond Lam of the University of British Columbia in Vancouver realized that many of his patients fared worse in January than in June. He has conducted studies in which he has bulimic women sit in front of light boxes every day, and after only a couple of sessions both their psychological and eating difficulties seemed to ease.

Sleep delay. Some people cannot fall asleep until very late at night and often cannot get moving again until 10 or 11 A.M. The reason: their internal clocks are out of phase with the natural day-night cycle. In some cases, extended bouts can inexplicably reverse: sufferers crash by early evening and end up waking hours before dawn. Scott Campbell, a chronobiologist at New York Presbyterian Hospital/Weill Cornell Medical Center, has had some success correcting this phase problem; people who fall asleep too late are exposed to light in the early morning, whereas the early risers will get the light at night.

Shift workers. One week they work 8 A.M. to 4 P.M.; the next week their schedule is from midnight to eight in the morning. Almost no shift worker escapes the consequences of this circadian whiplash. At a minimum, many become fatigued and have trouble concentrating when working nights. Although their inner clocks can adjust, the transition takes several days, and then almost immediately they must switch back. Researchers have found that shift workers make the transition much more easily when the workplace is bathed in at least 1,200 lux of light—what would be found in a bright office. Often, however, occupational safety laws require only 500 lux or so.

Jet lag. After a trip across many time zones, an individual's circadian clock usually needs several days to reset. The most obvious symptoms are sleep problems. Researchers disagree about whether light therapy can speed the reset process, but doctors nonetheless urge long-distance travelers to get as much daylight or bright light as possible during the first few days. Some hotels now offer in-room light boxes or special lamps that simulate sunrise to help the jet-lagged adjust. —*U.K.*

CORBIS

side every cell. But the two "alleles" are not necessarily identical; there is a short version and a long version. In 1998 a research group led by Rosenthal at the NIMH found that people with at least one short allele are more prone to seasonal depression and to more severe symptoms. Multiple studies have found a hereditary pattern, too; in the families of SAD patients, 13 to 17 percent of immediate relatives also suffer from seasonal depression. In the general population, the rate varies from 1.4 to 9.7 percent depending on the distance from the equator.

Genes, changes in levels of important hormones and neurotransmitters, an out-of-sync circadian clock—many factors seem to play a role in seasonal depression. But this disorder makes one thing clear: even in the 21st century, human beings are not independent of nature. Our inner clocks still track the seasons. For all we know, evolution may favor sluggishness in fall and winter as a way to promote physical and psychological renewal. Perhaps the problem is that in today's world such a life in tune with the seasons is no longer possible, and the SAD individuals are trying harder to preserve human nature. M

(Further Reading)

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Just a Bit Different

With special training early in life, children born with Down syndrome have a higher chance of developing into independent individuals

By Ingelore Moeller

In the mid-1800s English doctor John Langdon Down was appointed director of a home outside London for mentally handicapped children, where he studied their symptoms. In 1862 he described the case of one of his wards who was short and had stubby fingers and unusual eyelids. The boy's condition was later labeled with his surname. But the genetic cause of Down syndrome was not uncovered for another century. In 1959 French pediatrician Jérome Lejeune discovered that these children have three copies of chromosome 21, instead of the standard two.

Chris Burke, an actor with Down syndrome, played a similarly affected character on *Life Goes On,* a series that stressed the need to accept such individuals into society.

LAUREN SHEAR *Science Photo Library/Photo Researchers, Inc.* (*preceding pages*); COURTESY OF EVERETT COLLECTION (*this page*)

For too long, people with Down syndrome, or trisomy 21, have been dismissed as "retarded" and thus incapable of having rich lives. But that view has begun to change. Psychologists, doctors and special-education teachers now realize that a diagnosis at infancy does not necessarily mean a child will have few options in life—as long as he receives special training early. And socially, Down syndrome children are finally being accepted as unspectacular, everyday kids, in part thanks to the 1990s hit ABC television series *Life Goes On,* starring an actor with Down syndrome, Chris Burke, who today is 40.

Physical limitations continue to challenge these individuals. Poor muscle tone (which often causes the tongue to protrude from the mouth); joint trouble; pale, sensitive skin; and vision, hearing and thyroid problems are prevalent. About half suffer from congenital heart defects. But medical progress in the past two decades has doubled the average life expectancy from 25 to 50 years. For those without heart defects, life expectancy is even higher. Yet for most, a rewarding mental and social life is their greatest desire—and their greatest challenge.

Third Copy Interference

Trisomy 21 is the most common chromosomal abnormality in humans. It affects one in every 800 to 1,000 live births. Today more than 350,000 Americans have Down syndrome. But why does having three copies of chromosome 21 cause the condition? With a completed map of the human genome, researchers are in hot pursuit of an answer.

Soon after scientists in the Human Genome Project finished describing chromosome 21 in 2000, they confirmed that within this chromosome are the genes that cause both Down syndrome and Alzheimer's disease. Neurologists had previously discussed a connection between the two disorders, because both involve an inadequate production of the neurotransmitter acetylcholine, one of the brain's messenger molecules. In a review of recent research, Nancy Roizen of the Cleveland Clinic and David Patterson of the University of Denver focused on a particular gene that is crucial to energy production and oxygen utilization inside cells. They speculate that a defect in this system leads to the production of aggressive oxygen free radicals—molecules that damage cells—which may play a role in both Down syndrome and Alzheimer's.

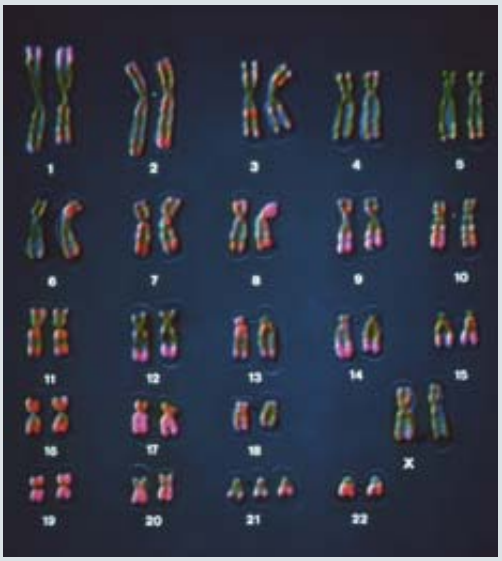
In 2004 Guilherme Neves and Andrew Chess, now at the Center for Human Genetic Research at Massachusetts General Hospital, tracked the roles played by other genes on chromosome 21—in this case using a fruit fly as the model. They found a gene—dubbed *Dscam* (Down syndrome cell adhesion molecule)—that appears to give every nerve cell a unique identity during prebirth development, making sure that each cell ends up in the right location in the brain and body. Neves

People with Down syndrome don't "suffer" from their disorder—only from bad treatment by others.

Chromosome 21: Three Instead of Two

Our genetic blueprint is stored in the chromosomes found in the nucleus of every cell in our bodies. There are 23 different bundles of DNA that normally exist in pairs, one copy each from the mother and father. They determine what people look like, how they develop and which diseases they may be vulnerable to.

A woman's egg and a man's sperm each contain a single set of the 23 chromosomes. The pairing occurs during fertilization, when the egg and sperm merge. On occasion, however, an egg or sperm may supply two copies of a particular chromosome, giving a fertilized egg—and thus every cell in the body of the future individual—three copies of that chromosome instead of two, and 47 chromosomes in total rather than 46. Most trisomies result in such devastating consequences that the embryo cannot survive and is rejected. But chromosome 21 is the smallest of the 23, and it seems that three copies of it may be less problematic; embryos with trisomy 21—the genetic cause of Down syndrome—do survive.



Caprice of nature: Individuals with Down syndrome have three copies of the smallest chromosome, number 21, instead of two and therefore have 47 total chromosomes rather than 46.

Geneticists have found that in 95 percent of babies born with trisomy 21, all body cells have 47 chromosomes. About 2 percent have mosaic trisomy, in which only some body cells have the third copy. The remaining 3 percent have translocational trisomy, the only inheritable form of Down syndrome; in this case, only parts of chromosome 21 are duplicated and attached to other chromosomes.

Babies with Down syndrome can be born into any family and to parents of any age or nationality. One well-documented risk factor, however, is maternal age. Ernest B. Hook of the University of California at Berkeley estimates that the risk of having an infant with Down syndrome is one in 1,500 for a 20-year-old woman but rises to approximately one in 20 for a 45-year-old mother-to-be. *—I.M.*

and Chess hypothesize that a different version of the gene may affect humans similarly. Because people with trisomy 21 possess an additional copy of this gene, the oversupply may hinder the establishment of correct connections among brain cells during fetal development.

Shortly before birth, the brain starts checking over its entire network and sorting out the superfluous connections, which are then pared down. But in one explanation, with trisomy 21 many of the unproductive connections endure. They constitute "dead ends" that slow the physical growth, learning and thought processes of people with Down syndrome.

Delayed Development

After birth, trisomy 21 children go through essentially the same developmental steps as other children, but their rate of progress is slower and varies much more widely. The range has been well documented by researchers such as Hellgard Rauh, a psychologist at the University of Potsdam in Germany, who has observed the progress of more than 30 Down syndrome children over several years.

Rauh has found that their mental development during the first three years of life proceeds, on average, about half as fast as normal, meaning most two-year-olds with Down syndrome have reached the same milestones as average 12- to 14-month-old babies. In the following years, the rate of mental development slows to about one third of that for normal children. Grasping, crawling and walking prove to be especially difficult hurdles in the first two or three years. Physical development lags behind, although after the third year the rate of mental development may catch up to a degree. Speech is often a problem; most Down syndrome children at the age of five

(The Author)

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More than 350,000 Americans have trisomy 21. Helping them obtain jobs and build households will dissolve long-standing prejudices, enriching everyone's lives.

SUSAN VAN ETTEN *Photo Edit*

or six—just before starting elementary school—are only beginning to speak in two- or three-word sentences. For example, when they want their favorite toy they will just say, "Ball!" and they will express their fear of a neighbor's pet by crying, "Dog!" Delays in language continue to plague many young people with Down syndrome right into adulthood.

For many trisomy 21 children, abstract thinking, such as dealing with numbers or geometric shapes, can be hard. They also have trouble with visual and linguistic symbolism, even with such simple concepts as same versus different and more versus less.

On the other hand, when Wolfgang Jantzen, a special-education expert at the University of Bremen in Germany, tested affected 11-year-olds—whose language skills were at about a four-year-old level—on spatial tasks, they performed almost age-appropriately. For example, he would give them a one-step problem such as "Place the yellow circle in front of the blue square," and they responded well. But if he added, "Before you pick up the yellow circle, touch the blue square," most of them would fail. The children had no trouble with the spatial placement, but the time-order sequence baffled them.

Also characteristic of children with Down syndrome is slower mental processing. Virtually all their reactions occur with a longer-than-usual time delay, which must be taken into account when working or living with them. Otherwise, misunderstandings will quickly mount. For example, a father may ask his seven-year-old son whether he would like a hamburger at suppertime. The boy may not respond immediately. The father may interpret the silence as a "no" and ask, "Would you rather have cheese?" "Yes," the boy might answer—and when he gets a plate with cheese, he may burst into tears because he was expecting the hamburger.

One tricky aspect of Down syndrome is that the children often realize they cannot accomplish many things that other kids their age can. They therefore seek to protect themselves when faced with challenges and, as Rauh explains, may

Children whose mothers are relaxed seem at ease. Those with controlling mothers seem insecure.

choose from several different strategies. Some try, with a combination of charm and feigned helplessness, to get other people to rescue them from difficult situations. Others manipulate their environment by clowning or throwing tantrums. And some will become honestly sad and simply give up. This resignation can be deep enough to set off psychosomatic disorders, such as chronic stomachaches.

Lively and Imaginative

While psychologists learn more about the thoughts going through the minds of Down syndrome children, parents, friends and teachers must still grapple with how to help these boys and girls reach their highest mental and social potential. It is becoming clear that the best way to encourage such growth is to interact with the children in lively, imaginative ways.

This positive support starts with the parents. Rauh observed that some mothers responded to their children's initiatives in play in a relaxed manner; they were attentive and friendly without trying to control what was happening, which cultivated an especially close attachment between child and mother. Other mothers remained detached from their son's or daughter's play, which left the child detached as well. When mothers seemed to have a need to be constantly involved by controlling and limiting the child's activity, it made the child insecure. Children who felt confident of their mother's interest behaved in a more relaxed way and presumably would adapt better to their surroundings.

Special "games" can help infants as well. Jutta Hatzer, a special-education teacher in Bremen, emphasizes simple measures designed to reinforce self-awareness during a child's first year of life. She demonstrated one exercise during a session with a one-year-old boy, Tom. She stood Tom in a large bucket filled halfway with dry beans, which reached his waist. The beans acted like little massage balls for the baby, who sat quietly and happily in his snug lair. "The enclosure provides security," Hatzer explains. "He can feel his body, sense his limits and get a firsthand notion of himself."

After a while, Hatzer encouraged Tom to grasp the beans. Everything proceeded slowly, step by step—the boy needed plenty of time to deal with each new situation. Hatzer sang simple, made-up songs describing each step ("Tom is in the bucket"). She repeated each phrase several times and soothed Tom with both words and gestures. Through this continuous communication and play the child learned to understand links between his internal and external worlds. This kind of early support, which for Tom began shortly after he was born, is designed to bolster his mental development so that it will be easier for him to learn to walk and talk later.

Some therapists recommend that caregivers use hand and arm gestures in conjunction with words. The children seem to learn gestures very quickly, helping them grasp the meaning of spoken words. For example, the boy mentioned earlier who got cheese instead of a hamburger might have better understood an accompanying gesture for "hamburger"—such as pretending to hold and bite the burger—which could have prevented the misunderstanding.

To bring Down syndrome children along, adults must also be careful not to appear standoffish or afraid of them. People with Down syndrome do not "suffer" from their disorder—only from inappropriately high demands from their environment. They are just a little different. They think differently, handle emotions differently, view things differently, look a bit different and sometimes react in ways we do not expect. They are full of originality and creativity but often do need a lot of encouragement for it to show. If those around them can accept them and be positive, they will develop into full personalities who know what they want and don't want.

One-year-old Tom is still too young to express his wishes. For him, being close to his mother is most important. She takes him into her arms, and he presses his little face into her neck. "What I hope for is that he can remain as happy and content as he is now and that he will always be well treated," she says. "That would be the nicest thing." M

(Further Reading)

- Information about and for people with Down syndrome and their families can be found at the Trisomy 21 Online Community at **http://trisomy21online.com/**
- Research advancements are tracked by the National Down Syndrome Society at **www.ndss.org/**

Want Clear Thinking? Relax

A short mental vacation can ease the stresses of the daily grind and prompt fresh ideas

BY CHARMAINE LIEBERTZ

DAY IN, DAY OUT, people believe they can win their headlong race against time by maintaining an excessively hectic pace. As soon as they wake each morning, the same questions plague their minds: "What do I have to accomplish today? How do I get it all done as quickly as possible?" The term "relaxation" is practically a dirty word.

At some point, such driven people are likely to hit the wall. Their built-up tensions will be unleashed on some unfortunate, unsuspecting person. Or they will find themselves in the hospital with a bleeding ulcer or heart palpitations. At a minimum, they will become less effective thinkers, defeating their very ability to accomplish mental tasks. Constant scrambling and extreme workloads may bring success short term, but the long-term, negative effects are serious.

Even children are feeling pressure to overachieve these days. At a young age, they already exhibit a pronounced tendency toward competitive behavior. In 2003 the Lucile Packard Foundation for Children's Health in Palo Alto, Calif., surveyed parents whose children were nine to 13 years old; 35 percent of respondents said they were moderately or very concerned that their children were under too much stress. More and more boys and girls are pressuring themselves to always be better than their peers in whatever they do. Their lives are overshadowed by a fear that they will not live up to their own goals or the demands of their parents and teachers.

It seems that many adults have lost the ability to simply switch themselves off from time to time—to take a break—and youngsters are not far behind. This is a scary development, because the ability to relax is an important prerequisite for optimal performance on the job and in the classroom—and for a healthy life. Our brains, bodies and personalities are hurt by constant stress. Under this condition, the brain sends ongoing

GETTY IMAGES

alarm signals in the form of high levels of the stress hormones epinephrine, norepinephrine and cortisol. Their presence raises a background level of anxiety that blocks the processing of information. The antidote is some purposeful downtime.

Go to the Mental Movies

Bosses and teachers, as well as employees and students, must understand that periods of relaxation are not a waste of time. We need breaks to quell stress, lower inhibiting hormone levels, clear out distractions and extend energy reserves. A little relaxation improves attention and concentration. Research by noted psychobiologist Ernest L. Rossi, in private practice in Los Osos, Calif., and others suggests that our bodies benefit most from a 20-minute reprieve about every one and a half to two hours. If we do not allow ourselves this recovery time, our performance will begin to deteriorate, and we will start to feel worn down. The losses may not be immediately evident, but they build up, depleting brain and body and making us agitated, aggressive, hypersensitive or depressed.

Dozing or being lazy for those 20 minutes is not the answer, however, in part because these states dull one's mental edge. Active relaxation relieves stress better yet keeps the mind primed.

The best active relaxation is a short mental vacation. Find a comfortable sitting position and close your eyes. Breathe calmly and regularly. In your mind, picture a particularly relaxing moment. Choose any scene you want, such as a quiet afternoon walk on a beach. During this imagined trip, think of as many sensations as possible—feel the soft sand between your toes, smell the salty air, hear the surf, enjoy the warmth of the sun on your face.

With only a modicum of practice, you will find that these "mental movies" can quickly lead to moments of deep relaxation.

To make your mental movies most effective, when you close your eyes think of a phrase to initiate the exercise each time, such as "I'm now going on vacation." Then focus all your attention on your breathing. When you begin to breathe in and out, fully expand and contract your lungs: inhale slowly for six seconds, hold the air for three seconds and exhale for six seconds. To help control your breathing, imagine there is a candle in front of you; you are not trying to blow it out but simply to make the flame flicker. Do this exercise a second time and take note of the letting go you begin to feel.

If you can repeat this cycle numerous times, your epinephrine levels will subside and feelings of stress and anxiety should taper off. Then you can really enjoy your mental vacation, whether you are at the beach or on a mountaintop. When you want to end the exercise, be sure to return to your surroundings as gently as possible. Try mildly contracting all your body muscles while slowly opening your eyes.

Younger children may find such guided relaxation too restrictive. Instead of focusing on breathing, it may be easier for them to think of "quiet time." Renowned Italian educator Maria Montessori discovered that most children love the quiet (which may seem unbelievable to many stressed-out parents) and respond well to the following instruction: "Close your eyes. Be completely quiet. Don't move. Hear the silence and listen to your body." And if young people find it difficult at first to develop a soothing mental image like a beach, read them a story, and they will readily transport themselves to an imaginary world, which is the real goal.

If a child has great difficulty keeping still and silent, calm background music can provide an ideal bridge. The same applies to adults who have trouble relaxing. Listen to melodic, instrumental music, allowing your thoughts to flow freely. For a short break at the workplace, imagining such music is enough—close your eyes and turn on your mental CD player. **M**

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Quick Fixes

If you can't make time during the workday for an occasional 20-minute mental vacation, you can partially relieve stress and prompt fresh thinking with a shorter trip:

Open a window, breathe in deeply and exhale. The increased flow of oxygen in your brain may allow subconscious ideas to more readily flow into consciousness.

Imagine pushing or lifting a heavy object, which will automatically tense the muscle groups needed for that activity. Circulation increases, bringing more oxygen to your neurons.

Follow the second hand of a clock. Thoughts clogging your mind will fade, and other thoughts will begin to creep into your awareness.

Close your eyes, then turn up your eyeballs as if you were looking at the ceiling. This movement automatically activates alpha waves in the brain, which help to hasten feelings of relaxation.

Stand with your feet shoulder-width apart. Slowly tense and relax your muscles, from bottom to top: first curl the toes, then clench the calves, the thighs, the buttocks, stomach muscles, hands, forearms, upper arms, chest and back. Finally, contract all the muscles in your face. The physical tension will relieve mental tension.

—*C.L.*

AARON WINDSOR *Getty Images*

A Healthy Laugh

Got problems? A little humor will help you get past them—and could even ward off illness

BY CHARMAINE LIEBERTZ

ANYWHERE IN THE WORLD, a smile conveys a universal point: "I'm friendly, and we can get along." Shared laughter goes even further, implying a kind of secret bond among the participants. For each of us personally, mirth affords a certain distance from our defeats. Comedian Bill Cosby hit the nail on the head when he said, "If you can laugh at it, you can survive it." And as research on the subject grows, it is becoming more evident that laughing can make us healthier physically as well as mentally.

Laughter begins as an uncontrollable reflex when babies reach about four months of age. Soon they may giggle up to 400 times a day. Once in preschool, children playing with verbal nonsense, puns and tongue twisters learn that when they say things that make other children laugh, the others become interested in and like them.

Unfortunately, as children get older they are also taught to downplay this social tool by parents and teachers who emphasize the seriousness of life. The attitude seems to be: if you're laughing, you're not learning. As a result, educators often neglect humor. This is a big mistake because students learn better when teachers can present material in an amusing way. A comic anecdote helps children remember, and an entertaining approach creates a more relaxed, anxiety-free learning atmosphere.

Even the act of chortling itself seems to improve memory. Psychologist Kristy A. Nielson of Marquette University read a list of 30 words to subjects and showed some of them a funny video clip afterward. One week later the participants who had been exposed to the clip within 30 minutes of having heard the list remembered 20 percent more words as those who had not.

More generally, a good guffaw is just plain healthy. Rod Martin, a psychologist and laughter researcher at the University of Western Ontario in Canada, theorizes that laughter improves mental performance by accelerating the heartbeat, thus increasing oxygen supply to the brain. Humor also provides temporary relief from everyday problems; psychologists note that people who learn to chuckle at their own foibles, rather than letting annoyances eat at them,

COURTESY OF BIG APPLE CIRCUS

Children with long-term illnesses fare better medically and mentally after visits by "doctors" from the Big Apple Circus's Clown Care Unit.

When we laugh, the brain releases chemicals that decrease pain, **reduce stress** and raise antibody levels.

may find solutions to their problems easier to come by.

It is not even necessary to laugh out loud to improve thinking. A discreet grin can go a long way because the changes in facial muscles trigger positive emotional signals in the brain. People who manage a smile will often be rewarded with a better mood.

The Best Medicine

Researchers have been studying the effects of laughter on well-being for decades. The case of *Saturday Review* editor Norman Cousins, who did not die until 1990 after having developed a chronic spinal disease in the 1960s, drew the attention of scientists to the possible therapeutic application of humor. When his physician was unable to help him with his excruciating back pain, Cousins wrote his own unconventional prescription: he spent hours a day watching slapstick movies and reading humorous literature. His success was astounding: after several months, Cousins claimed that he was nearly free of pain.

One of the founders of gelotology (*gelos* is Greek for "laughter"), Stanford University professor William F. Fry, also experimented on himself in the early 1960s. He drew blood samples at regular intervals while watching Laurel and Hardy and other comedic movies and had the samples analyzed. He found that laughter enhanced the activity of certain immune system cells responsible for killing infectious pathogens.

Since then, the science of pleasure has become a recognized discipline. Researchers such as immunologist Lee S. Berk of Loma Linda University have conducted numerous clinical studies that confirm the following physiological changes when we laugh:

- The pituitary gland releases its own opiates, which suppress pain.
- The production of immune cells increases.
- The level of the hormone cortisol, which is chronically high when an individual is under long-term stress and which suppresses the immune system, is reduced dramatically.
- Levels of the hormone epinephrine, which plays a role in hypertension and heart failure, decrease.
- Antibody levels in the blood and saliva rise.
- The number of natural killer cells increases, which accelerates the body's natural anticarcinogenic response.

Other experts have uncovered health benefits in unusual ways, notably Michael Christensen, co-founder of the Big Apple Circus in New York City. When he first began "clown doctoring," he scarcely imagined how successful the project would become. Today the circus's Clown Care Unit employs more than 90 jokers dressed as doctors who visit pediatric units at hospitals in New York, Boston and other cities. Their mission is to use humor to make life a bit easier for young patients who must endure long hospital stays for such ills as cancer and diabetes. Many of the children fare best when the clowns arrive; the interaction helps them tolerate their condition.

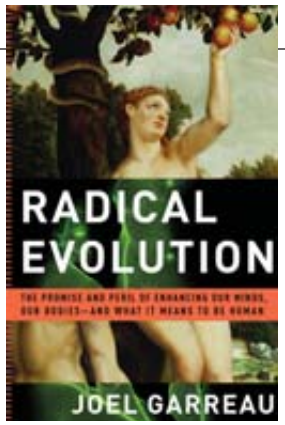
So when life is getting you down, laugh. If you can't find a source of humor, then at least find a mirror and smile at yourself for a moment. Even though that might not eliminate your work stress or annoyance at your children, it will improve your mood and create a little distance between yourself and your problems, at least temporarily. **M**

CHARMAINE LIEBERTZ is head of the Association for Holistic Learning in Cologne, Germany.

Only Posthuman

Radical Evolution: The Promise and Peril of Enhancing Our Minds, Our Bodies—and What It Means to Be Human

by Joel Garreau. Doubleday, 2005 ($26)



Is technology about to transform humanity? And would this be good? In his thought-provoking book, *Washington Post* reporter Joel Garreau parlays interviews with technologists and pundits into diverse scenarios of how genetic, robotic and other technologies might alter human prospects and even lead to a "posthuman" world.

In Garreau's "Heaven" scenario, technology makes people smarter, stronger and happier. Computer scientist Ray Kurzweil, for one, forecasts a growing convergence of humans and intelligent machines; ultimately, Kurzweil believes, people will be immortal, existing as "software" that can operate in various bodies. As an alternative heaven, biomedical futurist Gregory Stock sees genetic engineering as a way to continual mental and physical upgrades.

In the "Hell" scenario, political analyst Francis Fukuyama frets that genetic engineering will undermine democracy and the fundamental equality among citizens it fosters. Computer-networking pioneer Bill Joy fears that humanity might be enslaved or exterminated by smart robots and that self-replicating nanobots could bury the planet in "gray goo."

Heaven and Hell assume that the future will be driven inexorably by rapid technological change. Another scenario, "Prevail," is less predetermined; human choices, cultures and values more strongly shape technological developments, which are sometimes slowed or reversed. One version of Prevail comes from virtual-reality maven Jaron Lanier, who expects that technology will give people greater and more varied connections to one another.

In the end, Garreau sides largely with technology's enthusiasts over its critics. He presents a "Transcend" scenario in which humans embrace radical technologies while developing practices and institutions needed for this new world, such as gift giving to ensure that advances are broadly distributed. In this picture, people get much of Heaven while limiting the scourges of Hell.

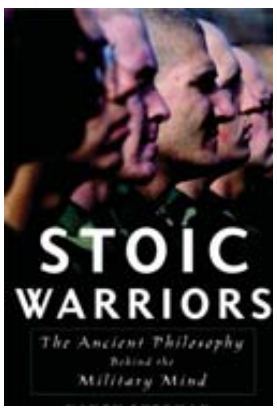
Radical Evolution has some weaknesses. Garreau's interlocutors do not always fit neatly into his categories. Also, Garreau sometimes overstates the imminence of technological change beyond the plausible. Altogether, though, the book is a valuable contribution to an important debate about the human—and possibly posthuman—future.

—Kenneth Silber

Mind Reads

Suck It Up

Stoic Warriors: The Ancient Philosophy behind the Military Mind



by Nancy Sherman. Oxford University Press, 2005 ($26)

In this age of live combat coverage, war's ravages are well known. Soldiers witnessing horrendous carnage often become numb and tortured souls, painfully reliving battle moments. Yet these same soldiers must move on, despite psychic trauma. In *Stoic Warriors,* Nancy Sherman addresses how soldiers gird themselves for combat. "This book is about 'sucking it up,'" she notes—about the role of Stoicism in modern life. A philosopher at Georgetown University and, formerly, the U.S. Naval Academy, Sherman traces the origin of today's military training to the Stoics, a group of philosophers who flourished in Athens and Rome more than 2,000 years ago.

The Stoics' core message was that human emotions are not passive reactions but are subject to cognitive control. Thoughts, opinions and interpretations cause, mediate and shape emotions, which the Stoics saw as "something of an act of judgment and will, and a matter of our own responsibility." But Stoicism can also become extreme, enabling individuals to detach themselves to survive or to kill, which sometimes leaves the doer with lasting trauma. Blending analysis of ancient texts with modern history, anecdotes and tales from combat survivors, Sherman delves into soldiers' hearts and minds, revealing how Stoic thought prepared them for catastrophe, including discipline of mind and body, manners, demeanor, anger, fear, resilience and grief.

This issue could not be more pressing, as Sherman writes, "given the U.S. Army's expansion of 'stop-loss' orders to keep soldiers from leaving the service and the general malaise of a war in Iraq." Thousands of troops in Iraq and Afghanistan will suffer psychic trauma but feel that not toughing it out signals weakness. Others will fear the stigma of seeking help, worrying about dishonorable discharge or the shame of not bearing up.

Sherman argues that toughing it out stoically is both a blessing and a curse. She cautions that in pursuing self-reliance and self-mastery, we must also be aware of the need to fortify and renew ourselves through human fellowship, empathy and respect, while striving to "cultivate humanity." This wisdom, of course, applies just as meaningfully to modern peace as it does to ancient war.

—Richard Lipkin

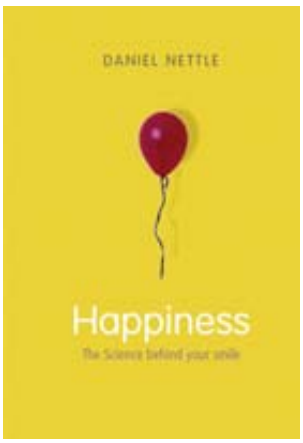
High on Life

Happiness: The Science behind Your Smile

by Daniel Nettle. Oxford University Press, 2005 ($21)

The right to "the pursuit of happiness" is enshrined in the Declaration of Independence, and Americans are obviously hot on the trail: they pop pills, go to therapy, and spend millions of dollars on self-help tapes. Daniel Nettle, a British psychologist, tries to explain what happiness is and critiques the methods people are using to achieve it. And although *Happiness* is far from a how-to book, Nettle does conclude with a bit of advice on finding it.

Nettle begins by defining the kind of happiness that interests him. Joy, the simple pleasure from finding lost money, is too trivial, and the "good life" is too much of a moralization. Instead his work focuses on "subjective well-being" or life satisfaction—which he says is what most people are seeking. Paradoxically, although many of the great European ponderers of the human condition—he quotes Freud, Sartre, Schopenhauer and others—agree with Western religions that life is a somewhat grim journey toward death, opinion surveys consistently show that people everywhere consider themselves fairly happy. They plan to be happier in the future, too. In light of this penchant, Nettle believes evolution has endowed us with a "happiness system" that allows us to feel satisfied with life yet remain convinced that if only we had another child, made more money or lost 10 pounds we would be truly happy.



Not all our pursuits are equally effective, he says. Americans today have far more money than their grandparents did; still, there is no sign they are happier. Having more social connections and good marriages, on the other hand, does promote satisfaction, and Nettle essentially equates happiness with satisfaction. He enlivens this discussion with some odd facts: people believe they can overcome almost any adversity, but living in constantly noisy places reduces happiness. And although most things money can buy quickly fade in value, breast implants seem to create a lasting high.

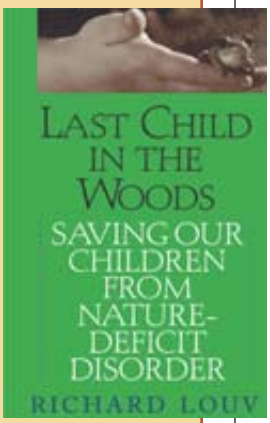
The book includes one chapter on the interactions of Prozac, opiates, ecstasy, and the serotonin and dopamine systems and how these compounds work in our brains to fight depression or induce feelings of pleasure. Yet Nettle does not consider biochemistry a source of happiness, and he moves on.

He concludes this pleasant, jargon-free book with some advice: total happiness is not attainable, but you can manipulate your mind and life to reduce the impact of negative emotion, increase positive emotion and—most important—stop consciously seeking happiness at all. He quotes an old joke about the Dalai Lama, who is visited by a rich acolyte bearing a huge, gift-wrapped box. The Dalai Lama opens the box to find it empty and exclaims, "Exactly what I've always wanted!" *—Jonathan Beard*

Losing Nature's Nurture

Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder

by Richard Louv. Algonquin Books, 2005 ($24.95)



Unstructured outdoor play was standard for me as a hyperactive child growing up in the rural Midwest. I fondly recall digging forts, climbing trees and catching frogs without concern for kidnappers or West Nile virus. According to newspaper columnist and child advocate Richard Louv, such carefree days are gone for America's youth.

Boys and girls now live a "denatured childhood," Louv writes in *Last Child in the Woods*. He cites multiple causes for why children spend less time outdoors and why they have less access to nature: our growing addiction to electronic media, the relinquishment of green spaces to development, parents' exaggerated fears of natural and human predators, and the threat of lawsuits and vandalism that has prompted community officials to forbid access to their land.

Drawing on personal experience and the perspectives of urban planners, educators, naturalists and psychologists, Louv links children's alienation from nature to attention-deficit hyperactivity disorder, stress, depression and anxiety disorders, not to mention childhood obesity. The connections seem tenuous at times, but it is hard not to agree with him based on the acres of anecdotal evidence that he presents. According to Louv, the replacement of open meadows, woods and wetlands by manicured lawns, golf courses and housing developments has led children away from the natural world. What little time they spend outside is on designer playgrounds or fenced yards and is structured, safe and isolating. Such antiseptic spaces provide little opportunity for exploration, imagination or peaceful contemplation.

Louv's idea is not new. Theodore Roosevelt saw a prophylactic dose of nature as a counter to mounting urban malaise in the early 20th century, and others since have expanded on the theme. What Louv adds is a focus on the restorative qualities of nature for children. He recommends that we reacquaint our children and ourselves with nature through hiking, fishing, bird-watching and disorganized, creative play. By doing so, he argues, we may lessen the frequency and severity of emotional and mental ailments and come to recognize the importance of preserving nature.

At times Louv seems to conflate physical activity (a game of freeze tag) with nature play (building a tree fort), and it is hard to know which benefits children most. This confusion may be caused by a deficiency in our larger understanding of the role nature plays in a child's development. At Louv's prompting, perhaps we will see further inquiry into this matter. In the meantime, parents, educators, therapists and city officials can benefit from taking seriously Louv's call for a "nature-child reunion." *—Jeanne Hamming*

Match wits with the Mensa puzzler

BY ABBIE F. SALNY

Head Games

1 For each line, find a word that matches the definition at the left and, when it is reversed, matches the definition on the right.

vegetable	_____	**part of a ship**
cooking utensils	_____	**important road sign**
give off	_____	**“4th dimension”**

2 Three sandwiches and five cups of coffee cost $20. Three cups of coffee and two sandwiches cost $13. What is the price of each sandwich and each cup of coffee?

3 An interesting question is coiled in the grid below. Start at the correct letter and move in any direction to find the question. (Start with a “D” and use each letter only once.)

A	H	O	S	D	O	B	U	R
S	E	U	E	N	W	R	U	N
D	O	B	U	R	N	O	?	P

4 A candy store owner prices sweets according to his own system. A gumdrop costs 12 cents; a lollipop costs 13 cents; a chocolate bar costs 19 cents. Using the same system, how much will a jujube cost?

5 A restaurant, whose owner is a puzzle fiend, was going to close for vacation. The note on the door, composed by the owner, read, “This is being posted on Wednesday, July 1. We shall be closed for vacation from the day after two days before the day after tomorrow.” What day of the week did the restaurant close for vacation?

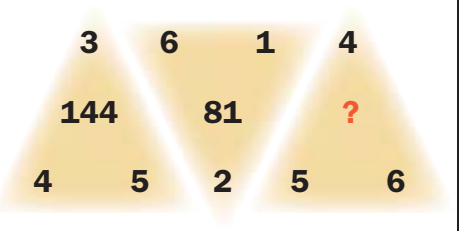
6 A bottle with a deposit for its return costs you $1.10. The bottle cost $1.00 more than the deposit. How much money are you going to get back when you return the bottle?

7 On a strange planet, the numerical system is such that 12 is half of 20. In that case, what is one fifth of 25?

8 In the following set of words, which one is “odd man out”?

Canada
Iceland
Netherlands
France

9 Fill in the missing number.



10 Charles is now half as old as Pat was three years ago. In three years, Charles will be half as old as Pat will be then. If neither is yet a teenager, how old are they now?

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. Leek, keel; pots, stop; emit, time.
2. Sandwiches cost $5; coffee is $1.
3. Does a house burn down or burn up?
4. Nine cents. Consonants cost two cents; vowels are a penny.
5. Thursday.
6. A nickel. Many people might say 10 cents, but that would mean the bottle costs $1.00, which is only 90 cents more than the deposit. The equation is X + $1.00 + X = $1.10, with X equaling the cost of the deposit.
7. The answer is 6. On this planet 5 = 6.
8. France. The other names begin with a three-letter word.
9. 225. Each number in the center is the sum, squared, of the numbers outside.
10. Charles is 4; Pat is 11.

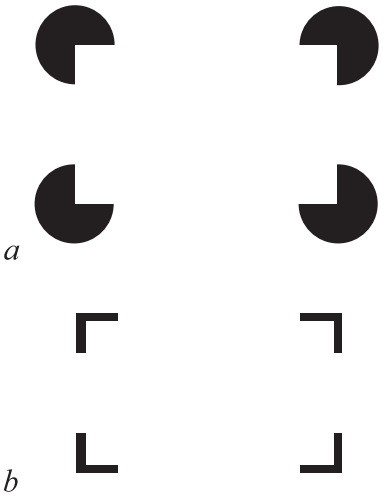
How can an imaginary square look more real than a box with actual lines? BY VILAYANUR S. RAMACHANDRAN AND DIANE ROGERS-RAMACHANDRAN

The Reality of Illusory Contours

COMPUTERS CAN CALCULATE at staggering speed, but they cannot match the human visual system's uncanny ability to assemble a coherent picture from ambiguous fragments in an image. The brain seems to home in effortlessly on the correct interpretation by using built-in knowledge of the statistics of the world to eliminate improbable solutions.

This problem-solving aspect of perception is strikingly illustrated in (*a*) by the famous illusory rectangle of the late Italian psychologist Gaetano Kanizsa and Richard L. Gregory, now emeritus professor of neuropsychology at the University of Bristol in England. Your brain regards it as highly unlikely that some malicious scientist has deliberately aligned four Pacmen in this manner and instead interprets it parsimoniously as a white opaque rectangle partially covering four black disks in the background. Remarkably, you even fill in, or "hallucinate," the edges of the phantom rectangle. The main goal of vision, it would seem, is to segment the scene to discover object boundaries so that you can identify and respond to them.

Now, you might think that the mere presence of collinear edges is sufficient for the brain to "complete" the



a

b

gap, but (*b*) demolishes this argument. Comparing the absence of illusory contours in (*b*) with their presence in (*a*), we conclude that the critical cue is *implied* occlusion.

In (*c*) and (*d*) we superimpose (*a*) on a background of bricks. Notice that in (*d*) the illusory contours disappear. The brain realizes that a rectangle must be opaque to occlude the four black disks. But if it is opaque, how can the bricks be seen through it? So the brain rejects this percept.

In (*c*) the bricks are aligned so that the edges coincide with the edges of the Pacmen. The occluding rectangle reemerges; indeed, it is actually more vivid than the illusory contour on its own. When multiple sources of information about an edge (in this case, the luminance-defined sides of the bricks and the illusory ones implied by occlusion) coincide spatially, the brain regards this coming together as compelling evidence that the edge is real.

How do we then explain the disappearance of the illusory rectangle in (*e*)—which could be logically interpreted as a textured rectangle occluding four gray disks in the background? To understand this anomaly, we need to invoke a "hardware" rather than "software" explanation. Notice that we have matched the mean luminance of the texture with that of the Pacmen. The neurons in your brain that extract the illusory edges can identify only those edges defined by luminance differences because of the way in which neurons evolved. Because the Pacmen in the display are defined by a difference of graininess, not luminance, no illusory contours are seen, even though the "logic" of the situation dictates that they should be.

In (*f*) we superimpose an illusory circle on a simple gradient of lumi-

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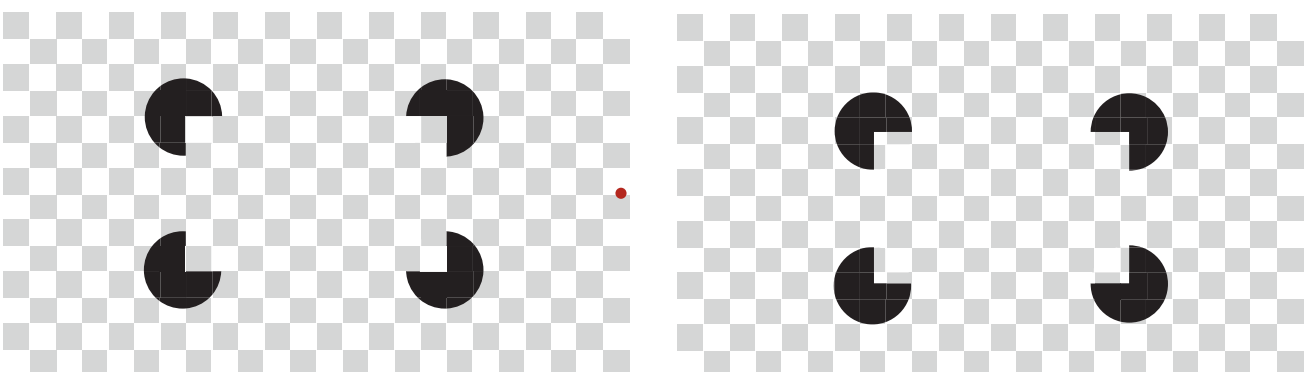
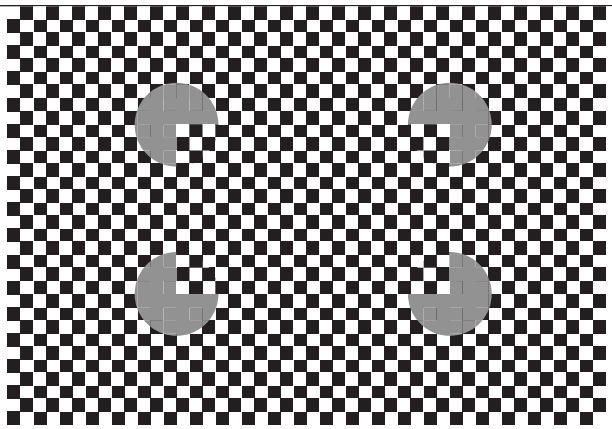


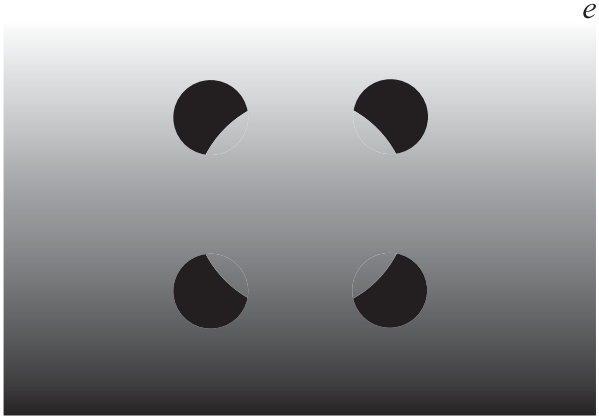
c

d

Your brain regards it as unlikely that some **malicious scientist** has deliberately aligned four Pacmen in this manner.



e



f

Continued from page 96

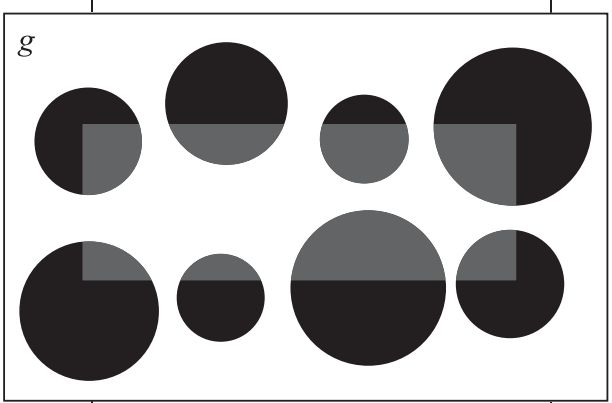
nance. Intriguingly the region enclosed by the circle seems to bulge right out at you, especially if you squint your eyes to blur the image slightly. The brain deduces that the gradient must arise from a curved surface lit from above, and the illusory circle interacts with this impression to produce the final interpretation of a sphere. Yet if we superimpose a "real" thin, black-outline circle made of an actual luminance-based edge on the gradient, no bulge appears. This finding leads to a paradoxical aphorism that we invented to annoy philosophers—namely, that illusory contours seem more real than real contours. Such luminance edges can arise in the visual scene for any number of reasons—the edge of a shadow, for example, or the stripes of a zebra. They do not necessarily imply object boundaries.

In 1961 neurobiologists David H. Hubel and Torsten N. Wiesel, both then at Harvard University, discovered the basic alphabet of vision (they later shared a Nobel Prize in Physiology or Medicine for their efforts to understand information processing in the visual system); individual neurons in area 17 and area 18 (in the occipital lobe) fire only when lines of a certain orientation are displayed in a specific location on the screen ("receptive field"). Many of them will respond only to a line of a specific length—if it is longer, they will stop firing ("end-stopped cells"). Neurophysiologist Rudiger von der Heydt of Johns Hopkins University suggested that these cells are signaling an implied occlusion that is effectively chopping off the line, and sure enough, the cells respond to illusory contours.

You can demonstrate the existence of such cells in your own brain. If you stare continuously at the red dot on the right of (*c*), you will notice that after a few seconds the illusory rectangle fades even though you still see the bricks and Pacmen. The cells signaling the illusory edges are "fatigued" by the steady fixation, which hyperactivates them and depletes them of their chemical neurotransmitters. If you move your eyes, they reappear, because a new set of cells is recruited. Apparently these illusory contour cells are more easily fatigued than those signaling the real edges of the bricks and Pacmen.

Finally, take a look at (*g*), devised by Kanisza. It initially appears to be an opaque horizontal rectangle with holes through which you can see another (horizontal) rectangle. But with some effort, you can "imagine" it as a semi-translucent veil-like smaller rectangle sitting on top of the black holes (or disks) on the larger one, and suddenly you see the illusory contours "completing" gaps across the holes. Thus, the complex rules of image segmentation incorporating the physical laws of transparency can be "applied" to the scene. Cells in the earliest stages of visual processing may signal illusory edges, but top-down modulation based on visual attention can reject or accept the contours depending on overall consistency with the scene. M

g



(Further Reading)

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