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page 58

SPECIAL REPORT

Want to Improve Your Memory?

Forget about It!

Learn to Erase Distractions

PLUS

You *THINK* You Remember

Eliminate Bad Thoughts

Sharpen Your Mind

SCIENTIFIC AMERICAN Travel

BRIGHT HORIZONS 15

OCTOBER 25 – NOVEMBER 5, 2012 ✷ E. MEDITERRANEAN ✷ www.InsightCruises.com/sciam15

BEEN THERE, DONE THAT? ITALY, TURKEY, ISRAEL, AND GREECE have drawn explorers over the span of 5,000 years. Bright Horizons is heading in to experience the region through new eyes, new data, and new discoveries as classical cultures and cutting-edge science converge in the Eastern Mediterranean. Share in the new thinking required by a changing world on **Bright Horizons 15** aboard the Costa Mediterranea, roundtrip Genoa, Italy, October 25–November 5, 2012.

Face the challenges posed by conservation planning and wildfire management, guided by Dr. Yohay Carmel. Dive into discoveries in astro-particle physics with Dr. David Lunney. Glimpse the neuroscience behind sensory perception and visual illusions with Dr. Stephen Macnik and Dr. Susana Martinez-Conde. Focus on developments in the nature and maintenance of memory with Dr. Jeanette Norden. Take in evolving thought on humankind's emigration from Africa with Professor Chris Stringer.

Discover the possibilities in environmental and neuroscience, particle physics, and anthropology. Visit archaeological sites and imagine the finds to come. Soak in the Mediterranean lifestyle. Savor the cuisine of Genoa. If you're game for field trips, we've designed behind-the-scenes experiences to extend your fun, from the European Organization for Nuclear Research, known as CERN, in Geneva to fascinating Herodium in Palestine. Send your questions to concierge@insightcruises.com or call 650-787-5665. Please join us!

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- Facing a New Mega-Fire Reality

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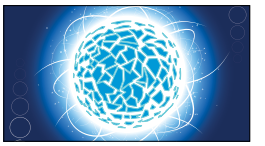
- How the Brain Works
- Memory and All That Jazz
- Losing your Memory
- Use it or Lose it!

COGNITIVE NEUROSCIENCE

- How the Brain Constructs the World We See
- Windows on the Mind
- Champions of Illusion
- Sleights of Mind



NUCLEAR ASTROPHYSICS

- A Hitchhiker's Guide to the Universe
- Nuclear Cooking Class
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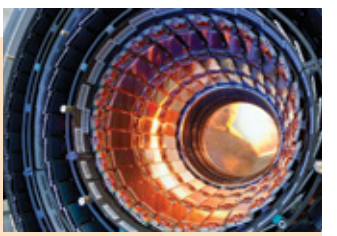
- Panning the Seafloor for Plutonium: Attack of the Deathstar

HUMAN EVOLUTION

- Human Evolution: the Big Picture
- The First Humans
- The Neanderthals: Another Kind of Human
- The Rise of *Homo Sapiens*

SPEAKERS

Yohay Carmel, Ph.D.
David Lunney, Ph.D.
Stephen Macknik, Ph.D.
Susana Martinez-Conde, Ph.D.
Jeanette Norden, Ph.D.
Chris Stringer, Ph.D.



INSIDER'S TOUR OF CERN

Pre-cruise: October 22, 2012—From the tiniest constituents of matter to the immensity of the cosmos, discover the wonders of science and technology at CERN. Join Bright Horizons for a private full-day tour of this iconic nuclear-research facility.

Whether you lean toward concept or application, there's much to pique your curiosity. Discover the excitement of fundamental research and get an insider's look at the world's largest particle physics laboratory.

Our full-day tour will be led by a CERN physicist. We'll have an orientation, visit an accelerator and experiment, get a sense of the mechanics of the Large Hadron Collider (LHC), make a refueling stop for lunch, and have time to peruse exhibits and media on the history of CERN and the nature of its work.

The price is $899 per person (based on double occupancy). This trip is limited to 50 people. NOTE: CERN charges no entrance fee to visitors.

EPHESUS

November 1, 2012—Many civilizations have left their mark at Ephesus. It's a complex and many-splendored history, often oversimplified. Bright Horizons pulls together three important aspects of understanding Ephesus that are rarely presented together. You'll meander the Marble Road, visit the legendary latrines, check out the Library, and visit the political and commercial centers of the city. A visit to the Terrace Houses will enhance your picture of Roman-era Ephesus.

We'll take a break for Mediterranean cuisine in the Selcuk countryside, then visit the Ephesus Museum in Selcuk, where city excavation finds are showcased, and you'll get a fuller look at local history, from the Lydians to the Byzantines.

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Time to Forget

I sat at a piano in a sun-filled modern church. The audience—other young pianists and their parents—watched as I played the first eight notes of a piece by composer Edvard Grieg. At the ninth note, I froze. I tried again: *da dee dee dee, da-da dee dee*. Silence. On the third try, chords tumbled from my fingers, and the piece flowed from there.

That event at age 14 was scarring, and I soon stopped taking piano lessons. Two years ago, however, I revisited that dormant memory as the band I joined much later prepared for its public debut. Too bad I'm a terrible performer, I thought gloomily.

But as this month's special report makes clear, recalling a memory also reshapes it. Memories are not preserved behind air locks in some squishy cellular vault. Rather they resemble clouds swirling in the currents. Change the conditions in which you remember, and the reminiscence twists accordingly, as journalist Ingfei Chen writes in "A Feeling for the Past," on page 24. In the mutable landscape of memory, a sharp mind must also delete thoughts selectively. *Scientific American Mind*'s Ingrid Wickelgren explains why in "Trying to Forget," on page 32. If letting things go is a struggle, the nuclear option—a pill to blot out the past—may soon offer respite, writes journalist Adam Piore in "Totaling Recall," on page 40.

Experiments on memory reveal how slippery our sense of truth can be. Stephen L. Macknik and Susana Martinez-Conde, experts on visual illusions, show how researchers exploit our error-ridden models of reality in "Mind-Warping Visions," on page 46. For a light take on our all-too-human inconsistencies, turn to "The Partnership Paradox," by NPR's Joe Palca and Flora Lichtman, on page 58. You will learn why your beloved's once alluring traits now seem so singularly annoying.

As for my botched recital, I no longer dodge the memory as if rotting vegetables were flying at my face. The problem, I now believe, was not stage stupor but my lousy practice record at the time. By rewriting that old memory to underscore effort rather than incapability, I shifted my sense of self—and my hopes for the future.

Sandra Upson
Managing Editor
editors@SciAmMind.com

SCIENTIFIC AMERICAN MIND
Volume 22, Number 6, January/February 2012

FEATURES

COVER STORY **SPECIAL REPORT** MEMORY

NOMA BAR (*heart*)

DEPARTMENTS

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OLDER AND MORE STRESSED

The article "Splintered by Stress," by Mathias V. Schmidt and Lars Schwabe, was very interesting. Have any studies been done on stress as it relates to a person's age? Being an older male (I'm 64) in the workforce, I have definitely noticed that my ability to handle stress in general has declined over the years.

George Stewart
Maitland, Fla.

SCHMIDT AND SCHWABE REPLY:

There is indeed some evidence that the way we handle stress and the way we are affected by it change with age. Studies show that older people typically have higher stress hormone levels throughout the day than younger people and are less able to terminate a sudden response to acute stress—they recover more slowly. Moreover, the brain regions that undergo the most rapid functional decline during aging (for example, the hippocampus) are also those that are involved in the regulation of our stress response systems. That does not mean, however, that older individuals are, by definition, not able to cope with stress. Individuals vary widely in their responses, determined both by genetic predisposition and by life history.

In general, exercise, a healthy diet and a good night's sleep should help both younger and older individuals to withstand the potentially adverse effects of stress.

HOW TO RELAX

I very much enjoyed Robert Epstein's article "Fight the Frazzled Mind," but I also feel that a major aspect of stress management needs to be clarified in future studies. Epstein describes four stress managing competencies: avoidance, source management, relaxation and thought management. Of these four, avoidance and source management are named as being the most effective. I believe the relative effectiveness of each competency has much to do with the fact that 83 percent of the study group was untrained to handle stress. It seems obvious to me that a person, unprepared to handle stress, would do better through avoidance than by attempting to use an unpracticed skill such as relaxation. What needs to be studied is the long-term effect of relaxation and thought management on stress.

Millions of people around the world who practice relaxation and thought management have found that the list of stress inducers in their life becomes shorter and shorter through the use of these techniques over a long period. Avoidance and source management may shorten the list in the present, but eventually we all must deal with life as it comes. That is where the long-term effects of relaxation and thought management bring huge benefits.

In other words, if you are heavily stressed and have no training in coping skills, avoidance and source management will indeed reduce your stress. But only with the long-term practice of relaxation and thought management will you have the possibility of eliminating the majority of stressors altogether.

Joe Lovotti
Agawam, Mass.

As a successful manager of and occasional educator about stress, I enjoyed Epstein's article until I was shocked by his heavy emphasis on planning. Making and struggling to adhere to plans in

How can we best reduce stress—plan to avoid it or practice relaxation?

an uncertain world constitute one of the greatest stressors there is. Meditation—which Epstein praises—teaches us that flexibility reduces stress, whereas rigidity escalates it exponentially, so learning to bend with the wind and alter plans when needed is key.

Scott Teitsworth
Portland, Ore.

LOVING RATS

Great rat story! Kelly Lambert's writing in "A Tale of Two Rodents" is a blissful mix of humor and erudition, and the illustrations by Kate Francis are fabulous.

Never in my quite long life have I written to editors before, but the rat story was so delightful, I had to give you strokes (to encourage your positive behavior). I always love your magazine, but the Lambert article is a gem among gems.

Wendy Delfeld
via e-mail

UNUSUAL VISION

I read "The Eyes Have It" [Illusions], by Susana Martinez-Conde and Stephen L. Macknik, with interest because I have early ("dry") macular edema, a condition that affects my eyesight. I was unable to fuse Albert Einstein's face clearly in the hybrid images. My inability to experience this illusion may be of interest in research because it implies, to me, a major influence of the macula not readily explained in the article.

To describe my macular defect in detail, I have sufficient vision to read a telephone book with 2.0 diopter correction and to see ordinary highway signs at ordinary distances with no correction, but I have trouble fusing small fine lines in near vision and seeing straight lines as straight.

I am an 83-year-old retired psychiatrist who has had a great interest in neuropsychiatry.

R. C. Rosan
via e-mail

EARLY SENTENCES

In regards to Kurt Kleiner's story "Lunchtime Leniency" [Head Lines]: others have observed that rulings are harsher when the judges are hungry. In "The Rape of the Lock," first published in 1712, Alexander Pope wrote this chilling couplet:

The hungry judges soon the sentence sign
And wretches hang that jurymen may dine.

Margo Sasse
Tucson

I was interested to read about the study of Israeli rulings on convicts' parole requests. Before attributing the higher rate of approvals at the beginning of a session to the breakfast or snack the judge ate just before starting, I would want to know what else the judge may have been doing before beginning the day or resuming the proceedings.

From my experience as a judge in Canada, I know that judges often organize their cases according to the time they are likely to require. Shorter cases are often dealt with first to allow busy prosecutors and defense attorneys who have narrowed the issue to one requiring only a few minutes of the judge's time to leave court and get on with the rest of their day. The cases are often reshuffled during a recess based on what the lawyers have told the judge before the recess about how long their cases are likely to take.

If the Israeli judges' approach is similar, that could explain why the requests that are dealt with at the beginning of the day or immediately after a recess are more likely to be approved. The longer, more difficult cases reserved for later in the day are not as likely to be slam dunks for the defense.

That is not to say that justice would not be better served if judges spent more of their recesses having a snack (or getting some brief exercise) instead of reviewing and prioritizing their next several cases. Limited judicial resources and the volume of work at busier courthouses can take a toll on the quality of judicial decisions, as well as on the health of judges.

David Price
via e-mail

SHOULD HAVE BEEN HERMES

In the solution to Head Games puzzle number 5, you name Mercury as a figure in Greek mythology. Mercury was, in fact, a figure in Roman mythology.

Bob Collins
via e-mail

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KYLE T. WEBSTER

>> ON THE JOB

Ripples of Rudeness

An unpleasant employee can spread stress far beyond the office

If you think that nasty co-worker is creating problems for you alone, think again. His rudeness may have a ripple effect that extends as far as your spouse's workplace. A recent study at Baylor University found that working with horrible colleagues can generate far-reaching stress that follows you home, causing unhappiness for your spouse and family and ultimately affecting your partner's job. The study was published in August in the *Journal of Organizational Behavior.*

Study author Merideth J. Ferguson, a psychologist and an assistant professor of management at Baylor, used statistical software to analyze the relation between employee reports of co-worker rudeness and reports by the employee's partner of home and work life. Not surprisingly, she found that exposure to rudeness created stress for both partner and family. She also found a direct correlation between the rudeness that the employee experienced and stress at the partner's workplace.

Keeping workplace stress outside the home can be difficult, especially when it is chronic, Ferguson says. Being treated unkindly by a colleague can cause loss of self-esteem, anxiety and depression, which undermines your happiness outside of work.

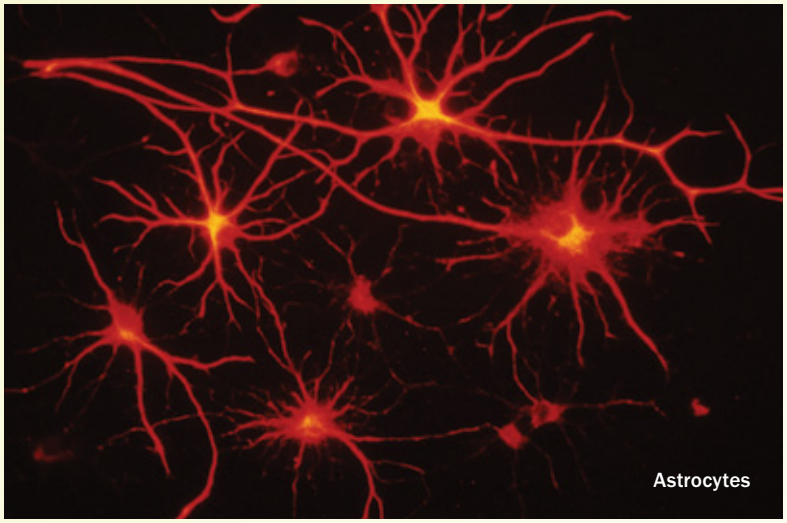
"Some people can successfully address that issue by being mindful of where they are and what they are doing," Ferguson says. To do that, she suggests focusing strictly on family and friends when at home and devoting your full attention to work when you are at the office. Talking to a counselor or psychologist about the stress or learning stress-management techniques (such as taking strategic breaks) can help, too.

—Winnie Yu

NEURODEGENERATION

When Helper Cells Attack

Brain cells known for assisting neurons may be killing them in patients with Lou Gehrig's disease



Astrocytes

Amyotrophic lateral sclerosis (ALS), also known as Lou Gehrig's disease, is a progressive neuromuscular disease that affects about 130,000 people worldwide a year. The vast majority of patients are isolated cases with no known family history of the disease. They usually start developing symptoms of the loss of motor neurons in middle age and die within five years of diagnosis. Researchers know very little about what causes ALS. Now a recent study in *Nature Biotechnology* suggests that the neuron death associated with the disease may be caused by astrocytes, a type of brain cell that normally helps neurons.

Previous research had suggested that astrocytes could become toxic in the rare form of ALS known to have genetic roots, and the study authors wanted to see if a similar phenomenon might happen in the more common isolated cases. The answer turned out to be yes: when they cultured astrocytes from those ALS patients, the healthy motor neurons in the culture began to die off after a few days. Other types of neurons were unaffected by the astrocytes, suggesting that they specifically harm the neurons involved in controlling the body's movements.

Lead author Brian Kaspar, a neuroscientist at Ohio State University, and his collaborators next will attempt to figure out what makes the astrocytes behave this way. If researchers can understand why motor neurons die in ALS, they may have a better chance of finding a cure. —*Erica Westly*

STEPHEN WAXMAN AND HANK MORGAN *Photo Researchers, Inc. (left)*; MIKE KEMP *Corbis (right)*

MEMORY

The Google Effect

The Internet has changed how our brain stores information

Four years ago Columbia University psychologist Betsy Sparrow turned to her husband after looking up some movie trivia online and asked, "What did we do before the Internet?" Thus, Sparrow set out to investigate how Google, and all the information it proffers, has changed how people think. Four psychology experiments later Sparrow has her answer, which was published in *Science* this past August. "[The Web] is an external memory storage space, and we make it responsible for remembering things," she says.

In one of Sparrow's experiments she presented two groups of undergraduates with trivia statements. Individuals in one group, who were told they could retrieve the information later on their computer, had worse recall than subjects in the other group, who knew in advance they could not do so. Together with the rest of her results, this finding suggests that Internet users have learned to remember how to find a fact rather than the fact itself.

Does this mean the Web is dumbing us down? Certainly not, she says: "Memory is much greater than memorizing." Our brain may simply be adapting to present circumstances, Sparrow points out. "We're in an Internet world." —*Anne Casselman*

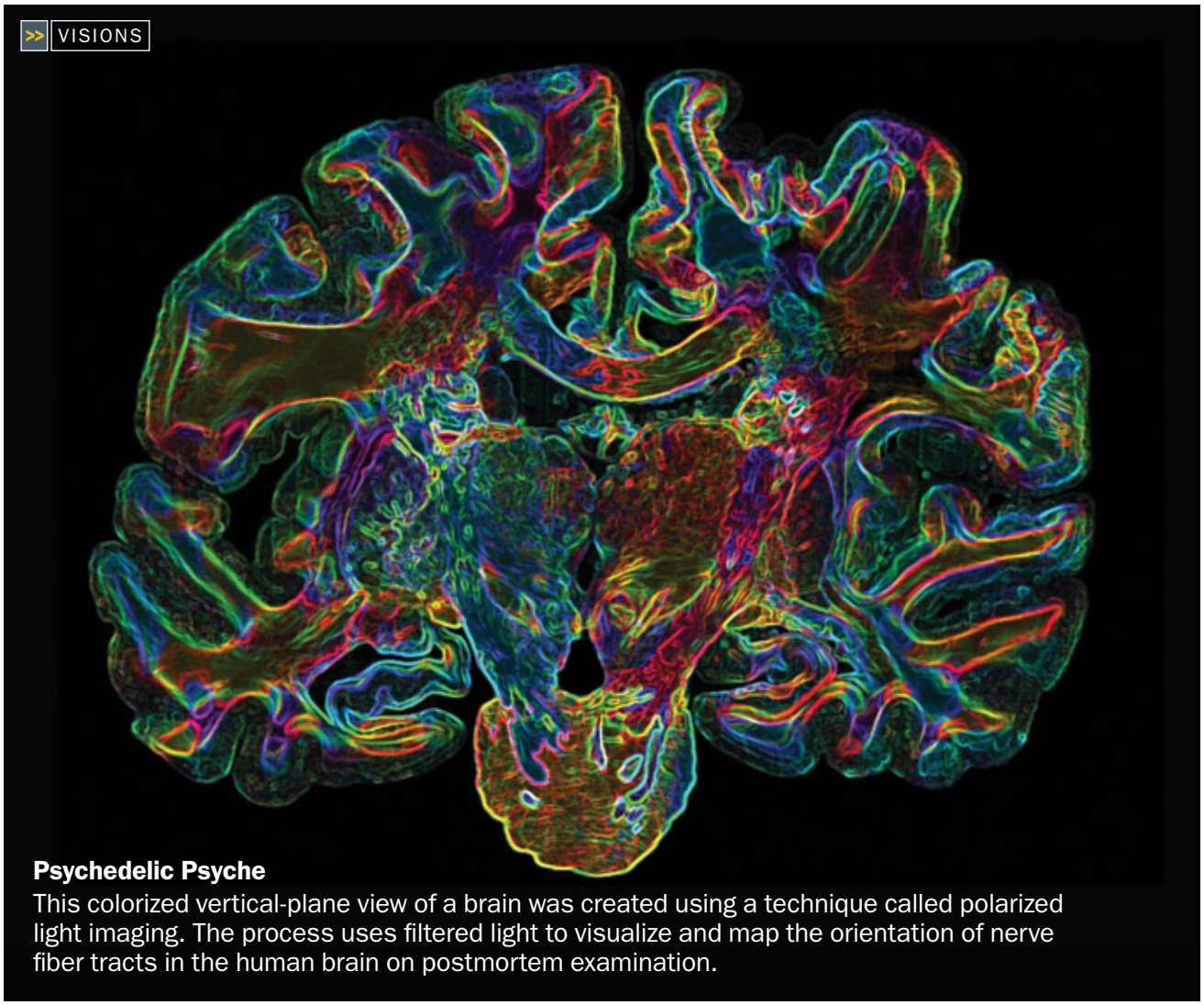
GET SHARP

Healthy Glow?

Not quite: people who regularly use tanning beds exhibit brain and behavioral changes similar to those seen in individuals who abuse drugs and alcohol.

HANS NELEMAN *Getty Images*

>> VISIONS



Psychedelic Psyche
This colorized vertical-plane view of a brain was created using a technique called polarized light imaging. The process uses filtered light to visualize and map the orientation of nerve fiber tracts in the human brain on postmortem examination.

>> BRAIN ACTIVITY

Mind the Animals

Certain neurons in the brain respond to pictures of animals

Whether cute and cuddly or fierce and frightening, animals affect the brain in ways scientists are just starting to appreciate. In a study of people who had electrodes implanted in their brain for the treatment of epilepsy, an international team discovered neurons that respond specifically to animals. The 41 individuals in the study were shown pictures of recognizable landmarks, objects, animals and people for about one second each as tiny electrodes measured the activity of individual neurons in three regions of their brain. When the researchers analyzed the electrical data from the 400 to 550 neurons in each region, they found a marked jump in the activity of neurons in the right amygdala that was not seen in the other brain regions tested—and only after viewing the pictures of animals. The report by senior author Christof Koch, a neuroscientist at the Allen Institute for Brain Science, and his colleagues appeared this past August online in *Nature Neuroscience*. (Koch also writes the monthly column Consciousness Redux for *Scientific American Mind*.)

Previous studies in animals hinted that the right hemisphere might be specialized for detecting prey or threats. Given the amygdala's proposed role in emotion and arousal, this finding led the team to speculate that the right-amygdala response might have evolutionary roots. More broadly, the fact that only the right side of the amygdala responds specifically to animals is tantalizing, Koch explains, because it is the first time this kind of hemispheric asymmetry has been found at the cellular level in the human brain. Imaging studies can detect only much larger shifts in activity. In this case, the patients being treated for epilepsy offered scientists a unique opportunity to examine such subtle brain responses. —*Andrea Anderson*

COURTESY OF KARL ZILLES AND KATRIN AMUNTS *Institute of Neuroscience and Medicine, Research Center Jülich (top)*; ISTOCKPHOTO *(bottom)*

>> NEURAL WIRING

The Stuttering Brain

A stutter indicates a massive change in brain wiring that affects more than just speech

Put on a pair of headphones and turn up the volume so that you can't even hear yourself speak. For those who stutter, this is when the magic happens. Without the ability to hear their own voice, people with this speech impediment no longer stumble over their words—as was recently portrayed in the movie *The King's Speech.* This simple trick works because of the unusual way the brain of people who stutter is organized—a neural setup that affects other actions besides speech, according to a new study.

Normal speech requires the brain to control movement of the mouth and vocal chords using the sound of the speaker's own voice as a guide. This integration of movement and hearing typically happens in the brain's left hemisphere, in a region of the brain known as the premotor cortex. In those who stutter, however, the process occurs in the right hemisphere—probably because of a slight defect on the left side, according to past brain-imaging studies. Singing requires a similar integration of aural input and motor control, but the processing typically occurs in the right hemisphere, which may explain why those who stutter can sing as well as anyone else. (In a related vein, *The King's Speech* also mentioned the common belief that people who stutter are often left-handed, but studies have found no such link.)

In the new study, published in the September issue of *Cortex,* researchers found that the unusual neural organization underlying a stutter also includes motor tasks completely unrelated to speech. A group of 30 adults, half of whom stuttered and half of whom did not, tapped a finger in time to a metronome. When the scientists interfered with the function of their left hemisphere using transcranial magnetic stimulation, a noninvasive technique that temporarily dampens brain activity, nonstutterers found themselves unable to tap in time—but those who stuttered were unaffected. When the researchers interfered with the right hemisphere, the results were reversed: the stuttering group was impaired, and the nonstutterers were fine.

According to lead author Martin Sommer, a neuroscientist at the University of Göttingen in Germany, the results suggest that the left-hemisphere defect underlying a stutter causes trouble with sensory integration in general, rather than specifically speech-related problems as was historically thought. "Like in stroke patients, the right side seems to jump in and compensate," Sommer explains. But that part of the brain did not evolve to handle those tasks, so problems—such as a stutter—can emerge.

—Carrie Arnold

>> MIND-SET

Get Out the Vote

A certain turn of phrase brings out people's best civic selves

Boosting voter turnout could be as simple as making individuals see voting as part of who they are rather than as something they do. For the 2008 presidential election, the turnout rate was about 96 percent among registered voters who first filled out a survey asking "How important is it to you to be a voter?" compared with about 82 percent for those who were asked "How important is it to you to vote?" The study, led by Christopher Bryan of Stanford University, was recently published in the *Proceedings of the National Academy of Sciences USA.* "We offered people the prospect of claiming a desirable identity," Bryan says. "That's a very powerful thing."

—Janelle Weaver

>> CONNECTIONS

When we blink, our world does not go dark. Blinking reduces activity in the visual cortex and other brain regions, which prevents us from noticing the change.

ISTOCKPHOTO (*top*); MIKE HIPPLE *Aurora Photos* (*bottom*)

>> NEUROSCIENCE

A Downward Spiral

Depression and drug addiction feed each other by altering the same brain circuit

Mood disorders such as depression are known to increase drug abuse risk. Yet mounting evidence suggests that substance abuse also makes people more vulnerable to depression and the negative effects of stress, according to Eric J. Nestler, chair of neuroscience at the Mount Sinai School of Medicine. He and his team reported new details about the link between depression and drug abuse in *Neuron* in August.

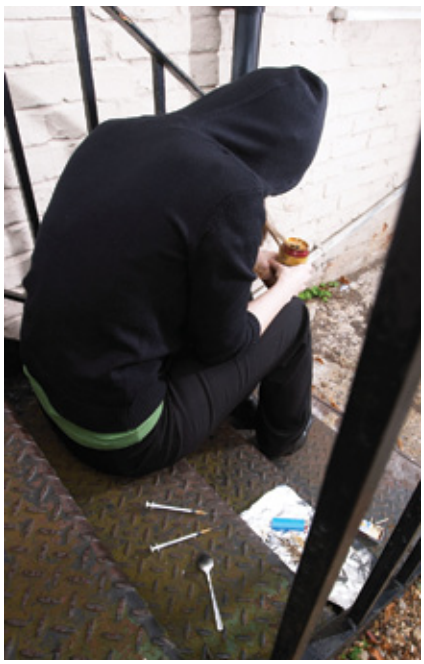
The team found that mice given cocaine daily for a week—a simulation of chronic drug abuse in humans—were more likely than their drug-free counterparts to display behaviors reminiscent of depression after being subjected to socially stressful situations involving an aggressive and intimidating mouse. The drug-treated mice became lethargic and reluctant to interact with other mice following a shorter-than-usual bout of this "social defeat" stress, which is commonly used to study depression in mice.

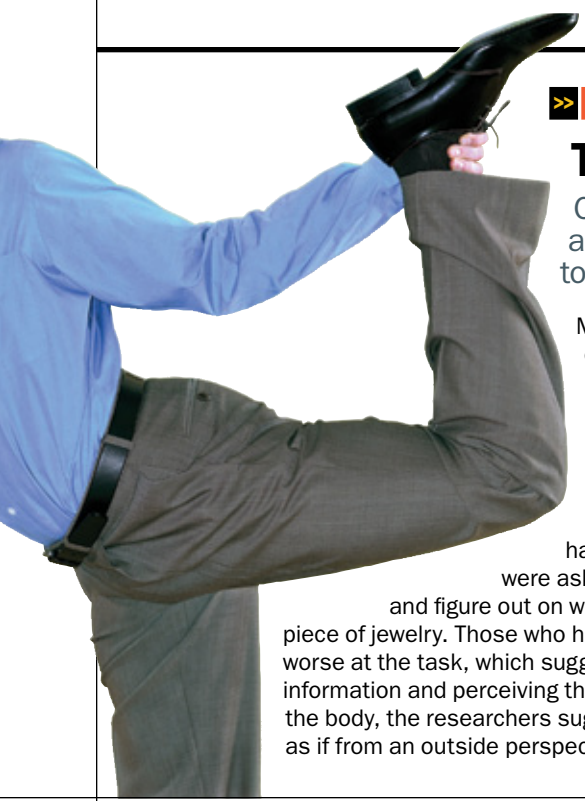
Most striking, the researchers found that the cocaine use led to the same molecular changes in the nucleus accumbens, a reward region, as are found in mice prone to stress and depression. The mice had lower levels of a molecule that polices the activity of certain genes and keeps at least one signaling circuit in check.

When the researchers artificially dialed down or up the levels of this regulatory molecule in the nucleus accumbens, they were able to produce or protect against depression in mice. This effect suggests that shifts in that brain region can cause—and are not just a side effect of—depression.

Testing for such changes in the human brain is trickier, of course. The team did find low levels of some of the same gene-regulating components in postmortem tissue samples from the nucleus accumbens of people diagnosed with depression, hinting that humans with the disorder might experience altered signaling in this brain region, too.

If so, the findings may provide clues about why cases of drug abuse and depression sometimes spiral out of control, given that drug-induced depression is believed to ratchet up the chances of subsequent abuse in the same way that naturally occurring depression can. —*Andrea Anderson*





>> MIND-BODY CONNECTION

That's Me over There

Out-of-body experiences are linked to a poorer ability to mimic unusual poses

Many individuals report having an out-of-body experience at some point in their life, and now scientists are homing in on the cause. A study published in *Cortex* in July hints that these strange perceptual illusions may arise from a less cohesive sense of one's own body. The researchers surveyed a group of psychologically healthy people and found that one in four had had an out-of-body experience. Then the subjects were asked to imitate the body position of a mannequin and figure out on which hand the dummy was wearing a distinctive piece of jewelry. Those who had reported an out-of-body experience were worse at the task, which suggests they had a harder time integrating sensory information and perceiving their body's position. This weaker internal link to the body, the researchers suggest, may make it easier to perceive the body as if from an outside perspective. —*Carrie Arnold*

>> HEAD COUNT

$63.2 BILLION

Annual cost of insomnia to the U.S. economy in lost productivity.

MALCOLM CASE-GREEN *Alamy (top)*; BRAD WILSON *Getty Images (bottom)*

PHOTO RESEARCHERS, INC.

>> SENSES

The Taste of Immune Suppression

An unusual flavor trains the brain to dampen the immune system

More than 100 years ago Ivan Pavlov famously observed that a dog salivated not only when fed but also on hearing a stimulus it associated with food. Since then, scientists have discovered many other seemingly autonomous processes that can be trained with sensory stimuli—including, most recently, our immune system.

Researchers have long been able to train an animal's immune system to respond to a nonpathogen stimulus. Pavlov's students even did so in the early 20th century, but the famous dogs overshadowed their work. Then, in the 1970s, researchers trained rats and mice to associate a taste, such as sugar water, with an immunosuppressive drug. They found that after repeated conditioning, ingesting the sugar water alone could tamp down the animals' immune response.

In 2002 a small study showed that the effect could be replicated in humans—at least on a onetime basis. By then, this training had already been used to prolong the survival of rats with heart transplants and slow the progression of lupus, arthritis and other autoimmune disorders in lab animals. But could human immune systems be trained to mimic a drug again and again?

"If it can be done only once, that's a very nice phenomenon for understanding the relation between the brain and the immune system," says Manfred Schedlowski, a medical psychologist at the University of Duisberg-Essen in Germany and a co-author of the 2002 paper. "But that's clinically useless." Last year Schedlowski published a study in the journal *Brain, Behavior, and Immunity* that aimed to find out whether the trained immunosuppressive response in humans could be sustained.

Thirty-two subjects were fed a green-colored, lavender-scented strawberry milk—an odd concoction designed to taste unique. For three days in a row, about half the subjects took an immunosuppressive drug along with the drink, whereas the other half took a placebo pill. After five days and then again another 11 days later, all the participants received a placebo pill along with the strawberry milk. Both times the immune systems of the experimental group were significantly inhibited after drinking the milk—as shown by levels of immunoresponsive molecules in their blood—whereas the control group was practically unchanged.

The study showed for the first time that learned immunosuppression can be recalled more than once in human subjects—encouraging news for patients on immunosuppressive regimens who must deal with the dangerous long-term side effects, such as high blood pressure and kidney failure. Although the researchers still need to figure out how to strengthen the conditioned effect and determine how long it will last, they hope one day to significantly reduce dosages of these drugs—and supplant them with harmless green milk and placebos.

—Lauren F. Friedman

>> PERCEPTION

Infant Kandinskys

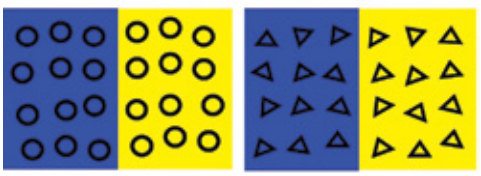
Babies are born with their senses linked in synesthesia

What if every visit to the museum was the equivalent of spending time at the philharmonic? For painter Wassily Kandinsky, that was the experience of painting: colors triggered sounds. Now a study from the University of California, San Diego, suggests that we are all born synesthetes like Kandinsky, with senses so joined that stimulating one reliably stimulates another.

The work, published in the August issue of *Psychological Science,* has become the first experimental confirmation of the infant-synesthesia hypothesis—which has existed, unproved, for almost 20 years.

Researchers presented infants and adults with images of repeating shapes (either circles or triangles) on a split-color background: one side was red or blue, and the other side was yellow or green. If the infants had shape-color associations, the scientists hypothesized, the shapes would affect their color preferences. For instance, some infants might look significantly longer at a green background with circles than at the same green background with triangles. Absent synesthesia, no such difference would be visible.

The study confirmed this hunch. Infants who were two and three months old showed significant shape-color associations. By eight months the preference was no longer pronounced, and in adults it was gone altogether.



Infants prefer certain shape-color pairings.

COURTESY OF KAREN DOBKINS AND KATIE WAGNER *University of California, San Diego*

The more important implications of this work may lie beyond synesthesia, says lead author Katie Wagner, a psychologist at U.C.S.D. The finding provides insight into how babies learn about the world more generally. "Infants may perceive the world in a way that's fundamentally different from adults," Wagner says. As we age, she adds, we narrow our focus, perhaps gaining an edge in cognitive speed as the sensory symphony quiets down.

—Maria Konnikova

>> THINK ABOUT IT

Are some of us predisposed to concussions?

YES

Researchers found that almost nine out of 10 athletes who experienced multiple concussions also had a variation of the apolipoprotein E genotype that does not allow neurons to heal themselves as easily.

>> MUSIC

Physically Out of Tune

Poor muscle control, not aural perception, underlies most cases of bad singing

A cringe-worthy chorus of "Happy Birthday" is usually all it takes to earn the label of "tone-deaf." Yet fewer than 1 percent of the population is truly amusical, that is, lacking the ability to distinguish different pitches. Many more of us simply can't carry a tune. A study published online in the *Journal of Experimental Psychology: General* reinforces scientists' growing belief that the culprit is not the ear but the throat. In a series of pitch-matching experiments, nonmusicians were pretty good at adjusting an instrument to match a specific note, suggesting that they could hear it just fine. They had much more trouble, however, imitating the same note with their own voice. The authors suspect that poor motor control of vocal muscles is partly to blame—findings that reinforce the idea that almost anyone can learn to sing. *—Lena Groeger*

>> MENTAL MAPS

Living in Two Dimensions

Our internal representation of the world is flat

When we drive somewhere new, we navigate by referring to a two-dimensional map that accounts for distances only on a horizontal plane. According to research published online in August in *Nature Neuroscience,* the mammalian brain seems to do the same, collapsing the world into a flat plane even as the animal skitters up trees and slips deep into burrows.

"Our subjective sense that our map is three-dimensional is illusory," says Kathryn Jeffery, a behavioral neuroscientist at University College London who led the research. Jeffery studies a collection of neurons in and around the rat hippocampus that build an internal representation of space. As the animal travels, these neurons, called grid cells and place cells, respond uniquely to distance, turning on and off in a way that measures how far the animal has moved in a particular direction.

Past research has focused on how these cartographic cells encode two-dimensional space. Jeffery and her colleagues decided to look at how they respond to changes in altitude. To do this, they enticed rats to climb up a spiral staircase while the scientists collected electrical recordings from single cells. The firing pattern encoded very little information about height.

The finding adds evidence for the hypothesis that the brain keeps track of our location on a flat plane, which is defined by the way the body is oriented. If a squirrel, say, is running along the ground, then scampers straight up a tree, its internal two-dimensional map simply shifts from the horizontal plane to the vertical. Astronauts are some of the few humans to describe this experience: when they move in space to "stand" on a ceiling, they report a moment of disorientation before their mental map flips so they feel right side up again.

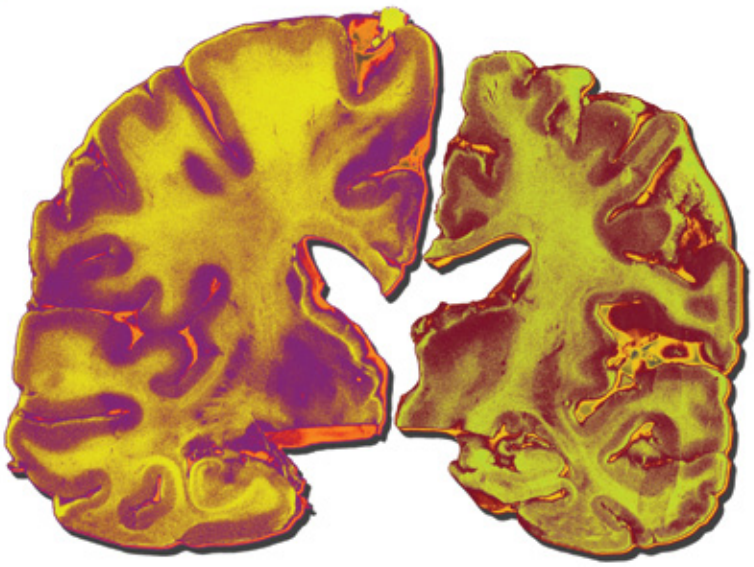
Researchers do not know yet whether other areas of the brain encode altitude or whether mammals simply do not need that information to survive. "Maybe an animal has a mosaic of maps, each fragment of which is flat but which can be oriented in the way that's appropriate," Jeffery speculates. Or maybe in our head, the world is simply flat.

—Morgen Peck

MORGAN DAVID DE LOSSY *Corbis (top)*; CORBIS *(bottom)*

>> TECH WATCH

Scientists have developed a new blood test for Alzheimer's disease that can accurately identify 93 percent of people who have the condition.



>> MEDICINE

An Early Warning Sign

Chemical changes in the brain predate Alzheimer's by decades in some patients

A preventive treatment for Alzheimer's disease is one of medicine's holy grails. Until recently, however, testing such a regimen would have been impossible—people do not have symptoms of dementia until it is too late. Now the Dominantly Inherited Alzheimer Network project, a large international study of those whose families suffer from a heritable form of early-onset Alzheimer's, has found that those who develop the disease have chemical changes in their brain decades before symptoms appear. Although the genetic form of the disease is rare, the discovery of these early chemical signals gives scientists a much needed group of people they can use to test potential deterrents. If a drug works on them, it would probably help the rest of the population, explained scientists at the International Conference on Alzheimer's in Paris this past July. [For more on these families and the quest to prevent Alzheimer's, see "Decoding Dementia," by Joel Shurkin; SCIENTIFIC AMERICAN MIND, November/December 2009.] *—Joel Shurkin*

JESSICA WILSON *Photo Researchers, Inc. (left)*; MICHELE CONSTANTINI *Corbis (right)*

>> COMMUNICATION

You Smell Angry

People can sense their partner's emotions via their body odor

You know you've been with your spouse a long time when you feel as if you have developed a sixth sense for his emotions—you can just *feel* when he is upset. It turns out you may actually be smelling his state of mind, according to a study reported this past June in the journal *Social Neuroscience.*

The researchers tested the ability of participants to identify, via body odor, their partner's or a stranger's chemosensory emotional cues—chemical compounds released by the body that have no noticeable odor but nonetheless transmit information about emotional states. First, the team placed pads in the armpits of "sweat donors" to capture their body odor as they watched videos intended to induce happiness, fear or sexual arousal, as well as when they were in a neutral mood. (Self-reported mood ratings were confirmed by measures of heart rate and skin conductance.) Next, they had partners smell the sweat samples to determine whether they could differentiate between emotional and neutral chemosensory cues. Although their ability to distinguish emotional sweat from neutral sweat was significantly above chance for both partners and strangers, their detection was more accurate for partners' samples and even more so the longer the couples had been together.

Participants were not able to identify the specific emotions represented by each sample because chemosensory emotional cues operate mostly at a subconscious level, unlike signals from facial expressions, voice or touch. The results, however, confirm what long-term couples have discovered time after time—communication happens on a surprising number of levels.

—Tori Rodriguez

>> FOOD FOR THOUGHT

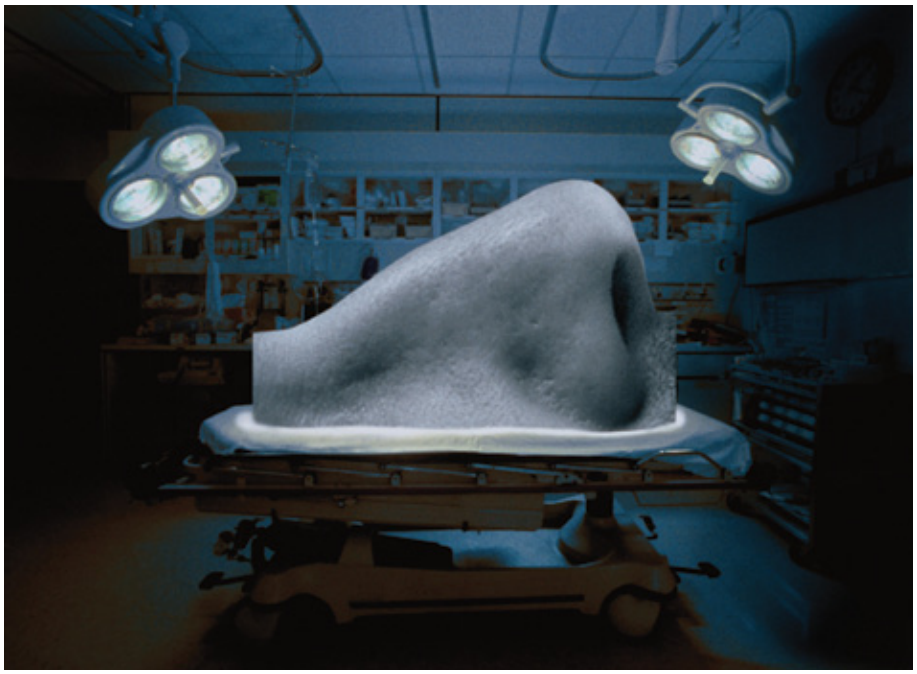
Eyeing the Chocolate

If you have trouble reading small print, reach for the dark chocolate. New research shows that the cocoa flavanols in dark chocolate can briefly sharpen vision—and even boost cognitive function—by temporarily increasing blood flow to the eyes and brain.

>> NERVOUS SYSTEM

When Viruses Invade the Brain

Neurodegenerative diseases may result from a nasal infection



Neurodegenerative diseases were once considered disorders of the mind, rooted in psychology. Now viruses rank among the environmental factors thought to trigger brain-ravaging diseases such as multiple sclerosis (MS) and Alzheimer's disease. Human herpesvirus-6 (HHV-6), in particular, has been linked to MS in past studies. Neuroscientist Steven Jacobson and his colleagues at the National Institute of Neurological Disorders and Stroke have determined that the virus makes its entry to the human brain through the olfactory pathway, right along with the odors wafting into our nose.

The researchers tested samples of brain cells from people with MS and healthy control subjects and found evidence of the virus in the olfactory bulb in both groups. Infection via the nasal passage is probably quite common, as is harboring a dormant reservoir of HHV-6, but in people with MS, the virus is active. Genetics and other unknown environmental factors probably determine the likelihood of the virus reactivating once inside the brain, which can cause the disease to progress.

The virus appears to invade the brain by infecting a type of glial cell called olfactory ensheathing cells (OECs), which nourish smell-sensing neurons and guide them from the olfactory bulb to their targets in the nervous system. These targets include the limbic system, a group of evolutionarily old structures deep in the brain, "which is where viruses like to reactivate," Jacobson explains. He points out that olfactory neurons and their OECs are among the few brain cells known to regenerate throughout our life. This neurogenesis may keep our sense of smell sharp, but at the cost of providing the virus the opportunity to spread. —*Stephani Sutherland*

>> BRAINPOWER

Your brain makes up about 2% of your total body weight but uses 20% of your body's energy.

ISTOCKPHOTO (*chocolate*); PATRICK McDONOGH Getty Images (*nose*); JAMIE CARROLL iStockphoto (*brain*)

What's in a Face?

The human brain is good at identifying faces, but illusions can fool our "face sense"

BY SUSANA MARTINEZ-CONDE AND STEPHEN L. MACKNIK

Our brains are exquisitely tuned to perceive, recognize and remember faces. We can easily find a friend's face among dozens or hundreds of unfamiliar faces in a busy street. We look at each other's facial expressions for signs of appreciation and disapproval, love and contempt. And even after we have corresponded or spoken on the phone with somebody for a long time, we are often relieved when we meet him or her in person and are able to put "a face to the name."

The neurons responsible for our refined "face sense" lie in a brain region called the fusiform gyrus. Trauma or lesions to this brain area result in a rare neurological condition called prosopagnosia, or face blindness. Prosopagnostics fail to identify celebrities, close relatives and even themselves in the mirror. But even those of us with normal face-recognition skills are subject to many illusions and biases in face perception.

SUSANA MARTINEZ-CONDE and STEPHEN L. MACKNIK are laboratory directors at the Barrow Neurological Institute in Phoenix. They are authors of the book *Sleights of Mind: What the Neuroscience of Magic Reveals about Our Everyday Deceptions,* with Sandra Blakeslee (http://sleightsofmind.com) (Henry Holt, 2010).

ILLUSION OF SEX

This illusion, created by psychologist Richard Russell, won third prize in the 2009 Best Illusion of the Year Contest. The side-by-side faces are perceived as female (*left*) and male (*right*). Yet both are versions of the same androgynous face (see http://illusioncontest.neuralcorrelate.com/2009/the-illusion-of-sex). The two images are identical, except that the contrast between the eyes and mouth and the rest of the face is higher for the face on the left than for the face on the right.

This illusion shows that contrast is an important cue for determining the sex of a face, with low-contrast faces appearing male and high-contrast faces appearing female. It may also explain why females in many cultures darken their eyes and mouths with cosmetics: a made-up face looks more feminine than a fresh face.

FOCUS ON FACES

Facial expressions play a key role in our everyday social interactions. Even when watching movies or looking at photographs, we spend most of our time looking at the faces they portray. Our intense focus on faces is at the expense of other potentially interesting information, however. Take a quick look at this woman and child. Their smiling faces suggest they are having a good time. But is that it? Look more closely, and you may notice that the girl has an extra finger on her right hand: something that you probably missed at first because your attention was fixed on the faces.

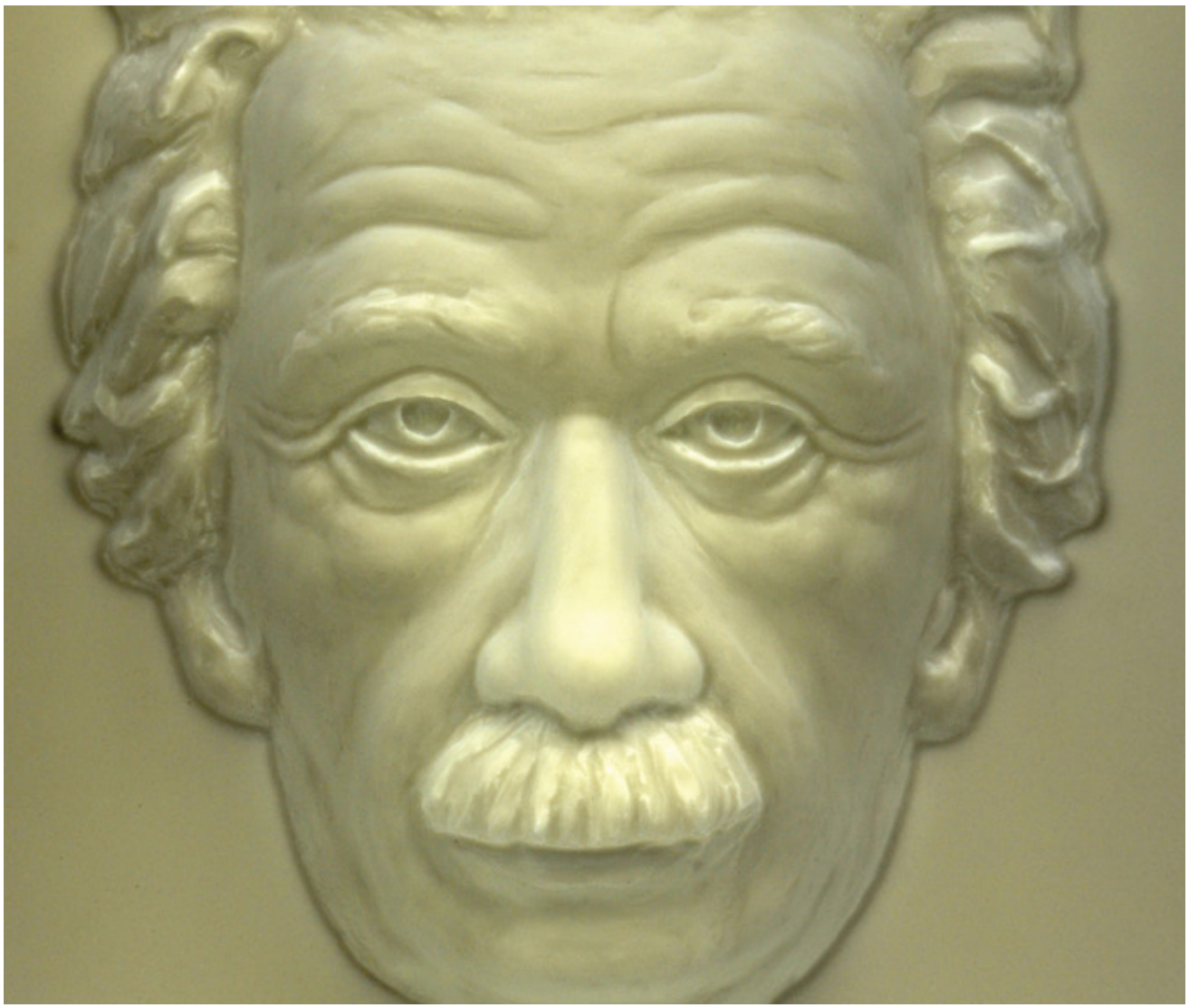
COURTESY OF RICHARD RUSSELL *Gettysburg College (left)*; THOMAS POLEN *iStockphoto*; PHOTOCOMPOSITION BY SMITHA ALAMPUR *(right)*



HOLLOW MASK ILLUSION

This hollow mask created by sculptor Bryan Parkes gives the eerie impression that Albert Einstein's face is following you as you move around the room (*below*). The mask is placed in front of a window, with its open back facing toward you, so that sunlight illuminates the plastic face. Although the mask is concave, your brain assumes that all faces are convex. While a convex face would look in only one direction, Einstein's hollow face seems to look forward when the viewer is directly ahead, but at an angle when the viewer moves sideways. In another demonstration of this well-known illusion, when a hollow mask rotates on a turntable, it appears to turn opposite to the actual direction of the turntable.

Vision researcher Thomas Papathomas of Rutgers University created an interesting variation on this illusion by attaching three-dimensional eyeballs and a nose ring to a hollow mask. As shown in these three frames from a movie of the rotating mask, the eyeballs and nose ring appear to rotate in the opposite direction to that of the mask (*above*). This illusion won third prize in the 2008 Best Illusion of the Year Contest. You can view the movie at http://illusioncontest.neuralcorrelate.com/2008/rolling-eyes-on-a-hollow-mask.

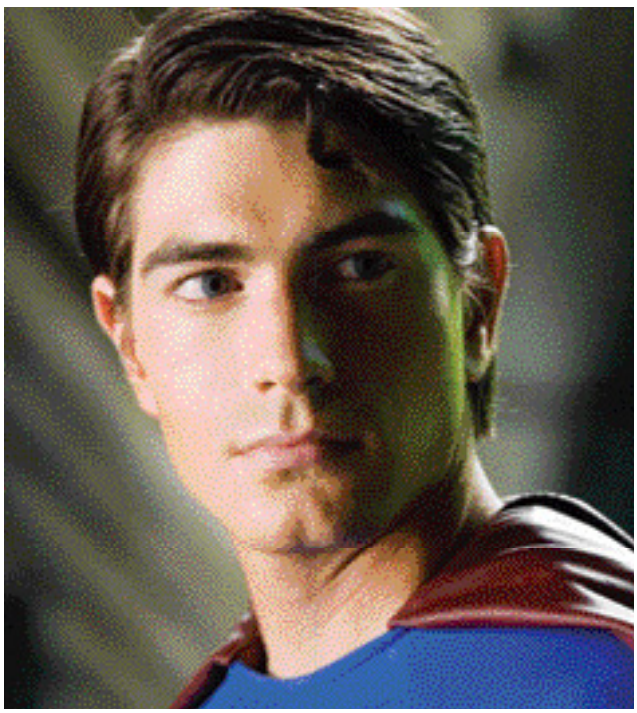


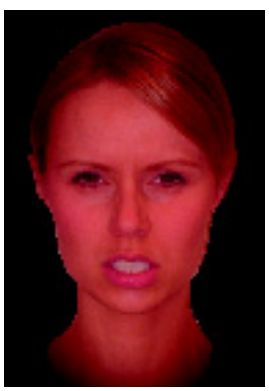
COURTESY OF THOMAS PAPATHOMAS *Rutgers University (top)*; COURTESY OF WWW.GRAND-ILLUSIONS.COM *(bottom)*

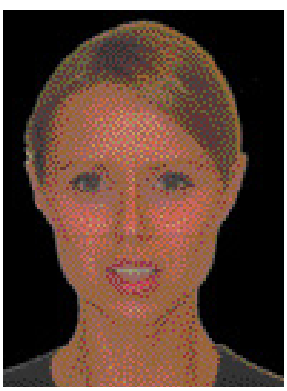
THE MANE DIFFERENCE

Visual illusions showcasing politicians are all the rage. At first sight it looks like Al Gore is standing behind Bill Clinton, but notice that Gore is really a doppelgänger Clinton, only with Gore's gorgeous head of hair (*left*). A set of face features (Clinton's) mixed with a different set of attributes (Gore's hair) isn't easily recognized as being misplaced.

Superman relies on the same illusion to protect his identity: thanks to a pair of glasses, a change of clothes and a different hairstyle, nobody in Metropolis realizes that he and Clark Kent are the same person (*below*).







EMOTION ADAPTATION

Gaze at the angry face (*left*) for about 30 seconds while looking around the face from the eyes to the mouth, to the nose, back to the eyes, and so on. Then look at the center face. It looks scared, right? Now look at the scared face (*right*) for 30 seconds and then look at the center face again. This time it is angry! In reality, the center face is a 50–50 blend of an angry and a scared face.

Created by Andrea Butler and her colleagues at the University of British Columbia, this illusion shows that our visual-processing system adapts to an unchanging facial expression by temporarily becoming less responsive to it. As a result, the other facial expression dominates when you view the blend. This adaptation occurs in higher-level brain circuits, rather than in the retina, because the illusion works even if you view the left or right image with one eye only and then look at the center image with your other (unadapted) eye.

TOP TO BOTTOM: COURTESY OF PAWAN SINHA AND TOMASO POGGIO *M.I.T.*; WARNER BROS./DC COMICS/THE KOBAL COLLECTION; FROM "FACTORS CONTRIBUTING TO THE ADAPTATION AFTEREFFECTS OF FACIAL EXPRESSION," BY ANDREA BUTLER ET AL., IN *BRAIN RESEARCH*, VOL. 1191; JANUARY 29, 2008. REPRINTED WITH PERMISSION FROM ELSEVIER

The Secret Inner Life of Bees

Provocative experiments suggest that insects have something resembling emotions

BY JASON CASTRO

Grumpy? Giddy? According to some measures, bees appear to experience moods.

CHARLES KREBS *Corbis*

IF YOU HAVE NEVER watched bees carefully, you are missing out. Look closely as they gently curl and uncoil their mouthparts around food, and you will sense that they are not just eating but enjoying their meal. Watch a bit more, and the hesitant flicks and sags of their antennae seem to convey some kind of emotion. Do those twitches signal annoyance? Or something like enthusiasm?

Whether bees really experience any of these emotions is an open scientific question. It is also an important one, with implications for how we should treat not just bees but the great majority of animals. Recently studies by Melissa Bateson and her colleagues at Newcastle University in England have rekindled the debate over these issues by showing that honeybees may experience something akin to moods.

Using simple behavioral tests, Bateson's team showed that honeybees under stress tend to be pessimistic. Other tests have demonstrated that monkeys, dogs and starlings all tend to react similarly under duress and likewise see the proverbial glass as half empty. Although this finding does not—and cannot—prove that bees experience humanlike emotions, it does give pause. We should take seriously the possibility that insects, too, have emotions.

Beeline to the Brain

First, a little bit about bees. They are members of the diverse group of animals lacking backbones—indeed, more than 95 percent of all animal species are invertebrates. Despite the varied and often nuanced behaviors they can exhibit, invertebrates are sometimes regarded as life's second string, a mindless and unfeeling band of alien critters. If that seems somewhat melodramatic, just consider our willingness to boil some of them alive.

Those judgments tend to arise from arguments about invertebrates' failure to demonstrate the behaviors we usually associate with a pain response. Whereas the yelps and grimaces of other mammals are familiar to us as announcements of hurt, invertebrates can appear to take their injuries in stride. Insects are commonly observed using their crushed limbs with undiminished force when walking, for example, and a locust will reportedly carry on with a meal while it is being eaten by a mantis.

Other attempts to draw a dividing line between creatures that feel and those that do not are rooted in comparative brain anatomy. Invertebrates lack a cortex, an amygdala and many of the other major brain structures routinely implicated in human emotion. Their nervous systems are quite minimalist compared with ours: we have roughly 100,000 bee brains' worth of neurons in our head. Some invertebrates, however, including insects, do possess a rudimentary version of our stress response system. So the question remains: Do they experience emotion in a way that we would recognize, or do they simply react to the world with an elaborate set of reflexes?

To gain some traction on this fascinating question, Bateson's team followed the lead of recent investigations on "pessimistic biases" in animals. In humans, the pessimistic bias refers to our well-known tendency to perceive threats or anticipate negative outcomes more frequently when we are feeling anxious or depressed. For example, in tests where people are shown ambiguous statements such as "the doctor examined little Emily's growth," anxious individuals are less likely than others to conclude that Emily is fine and only her height was being checked.

Although the link between bad moods and negative judgments may not be terribly surprising, this correlation is still useful. We rely on it in our daily lives to make informed guesses about how

Our criteria for **assessing animal emotions** should be blind to whether the animal has fur, feathers or an exoskeleton.

people are feeling by observing their actions and choices. Scientifically, we can use it to study the emotions of creatures unable to tell us directly how they feel. The key here is to set up a controlled situation where animals encounter an ambiguous stimulus—think of it as a nonverbal version of the Emily statement.

In the initial setup of Bateson's experiment, a group of honeybees was trained to associate two simple odor mixtures with two different foods. One mixture, which consisted of one part hexanol to nine parts octanone, was repeatedly paired with sucrose, which bees find rewarding. The other odor mixture consisted of the same two chemicals in opposite proportions (nine parts hexanol to one part octanone) paired with quinine, a compound that most of us find bitter and bees will actively avoid after tasting. By using this technique, the researchers hoped to overcome the bees' intrinsic responses to sucrose and quinine and test only their judgment of the new smells. After learning these odor-food associations, the bees responded as expected, uncoiling and extending their mouthparts in anticipation of food when the first odor mixture was presented and retracting them at offers of the second concoction.

This training allowed the scientists to study the bees' decision making by then testing their mouthing responses to a series of ambiguous odor mixtures. First, half the bees got a trip to the "vortexer." The experience was probably as unpleasant for them as it sounds to us. In a procedure meant to simulate a badger attack on a hive, the bees were shaken for one minute in a machine typically used to vigorously mix chemicals. If bees can indeed be made to feel cranky, surely this device would do the trick.

Next, both shaken and unshaken bees were tested on five mixtures of hexanol and octanone at different concentrations. Sure enough, both groups preferred extending their mouth to octanone-heavy mixtures, which predicted sugar, rather than hexanol-heavy mixtures, the scent of which predicted quinine. Interestingly, the shaken bees were less likely to advance toward any of the mixtures than their unperturbed counterparts.

In an analogue of the classic scenario of the half-empty glass versus the half-full glass, the bees were also presented with an equal mixture of hexanol and octanone. Bees that were spared the trip to the vortexer gave the concoction the benefit of the doubt, moving their mouth toward the food on close to 60 percent of the trials. Shaken bees, on the other hand, ignored or recoiled from these same ambiguous stimuli more than half the time. The stress of shaking had turned them into pessimists that interpreted the ambiguous odor as half threatening rather than half appetizing.

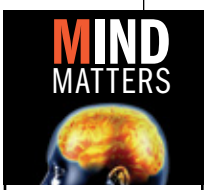
Both Shaken and Stirred

In addition to these behavioral measures, the scientists also tested for changes in the bees' neurotransmitter levels after shaking. The quantities of certain chemicals with known roles in insect learning (octopamine), aversive conditioning (dopamine) and aggression (serotonin) were all reduced by the procedure, suggesting that as with their mammalian counterparts, duress in bees causes sustained, system-wide changes in brain state—a possible analogue of mood. Together these behavioral and neurochemical tests reveal an unexpected dimension of bee cognition. Formally, we can say that when agitated, bees can take on a negative disposition, a state that alters both their thinking and their neurochemistry.

For now, however, we cannot conclude anything more sweeping about the emotional life of a bee. Bateson and her co-authors leave us with an intriguing plea for consistency, however, one that nudges us to think clearly about how we regard the minds and emotions of all creatures. Last year researchers tested dogs that appeared to suffer from separation anxiety for a pessimistic bias. When they encountered an uncertain food reward, the perturbed dogs also appeared less inclined to try the ambiguous treat, which the researchers interpreted as evidence that dogs indeed feel anxious when left alone. "It is logically inconsistent," Bateson and her colleagues say, to deduce that dogs and other similar animals express emotions "but to deny the same conclusion in the case of honeybees."

To put it another way, our criteria for assessing animal emotions should be blind to whether the animal has fur, feathers or an exoskeleton. Either bees and other invertebrates get a trial membership in the club of the genuinely anxious, or we must concede that our beloved pets' seemingly pessimistic actions imply nothing about their feelings. For a smitten dog owner, at least, the choice is probably obvious. M

JASON CASTRO is a postdoctoral fellow in the Center for Neuroscience at the University of Pittsburgh. He studies synaptic processing and plasticity in the auditory system.



Each week in Mind Matters, www.ScientificAmerican.com/mind-and-brain, researchers explain their disciplines' most notable recent findings. Mind Matters is edited by Gareth Cook, a Pulitzer Prize–winning journalist at the *Boston Globe,* where he edits the Sunday Ideas section.

(Further Reading)

- **An Integrative and Functional Framework for the Study of Animal Emotion and Mood.** Michael Mendl, Oliver H. P. Burman and Elizabeth S. Paul in *Proceedings of the Royal Society B,* Vol. 277, pages 2895–2904; October 7, 2010.
- **Agitated Honeybees Exhibit Pessimistic Cognitive Biases.** Melissa Bateson et al. in *Current Biology,* Vol. 21, No. 12, pages 1070–1073; June 2, 2011.

Movies in the Cortical Theater

Functional MRI can peer inside your brain and watch you watching a YouTube clip

BY CHRISTOF KOCH

UNLESS YOU HAVE been deaf and blind to the world over the past decade, you know that functional magnetic resonance brain imaging (fMRI) can look inside the skull of volunteers lying still inside the claustrophobic, coffinlike confines of a loud, banging magnetic scanner. The technique relies on a fortuitous property of the blood supply to reveal regional activity. Active synapses and neurons consume power and therefore need more oxygen, which is delivered by the hemoglobin molecules inside the circulating red blood cells. When these molecules give off their oxygen to the surrounding tissue, they not only change color—from arterial red to venous blue—but also turn slightly magnetic.

Activity in neural tissue causes an increase in the volume and flow of fresh blood. This change in the blood supply, called the hemodynamic signal, is tracked by sending radio waves into the skull and carefully listening to their return echoes. FMRI does not directly measure synaptic and neuronal activity, which occurs over the course of milliseconds; instead it uses a relatively sluggish proxy—changes in the blood supply—that rises and falls in seconds. The spatial resolution of fMRI is currently limited to a volume element (voxel) the size of a pea, encompassing about one million nerve cells.

Neuroscientists routinely exploit fMRI to infer what volunteers are seeing, imagining or intending to do. It is really a primitive form of mind reading. Now a team has taken that reading to a new, startling level.

A number of groups have deduced the identity of pictures viewed by volunteers while lying in the magnet scanner from the slew of map-like representations found in primary, secondary and higher-order visual cortical regions underneath the bump on the back of the head.

Jack L. Gallant of the University of California, Berkeley, is the acknowledged master of these techniques, which proceed in two stages. First, a volunteer looks at a couple of thousand images while lying in a magnet. The response of a few hundred voxels in the visual cortex to each image is carefully registered. These data are then used to train an algorithm to predict the magnitude of the fMRI response for each voxel. Second, this procedure is inverted. That is, for a given magnitude of hemodynamic response, a probabilistic technique called Bayesian decoding infers the most likely image that gave rise to the observed response in that particular volunteer (human brains differ substantially, so it is difficult to use one brain to predict the responses of another).

The best of these techniques exploit preexisting, or prior, knowledge about pictures that could have been seen before. The number of mathematically possible

> It is not inconceivable that the kind of **visual daydreaming** we all engage in will one day yield to the tool of magnetic scanning.

CHRISTOF KOCH (*Koch*); TODD DAVIDSON *Stock Illustration Source*

images is vast, but the types of actual scenes that are encountered in a world populated by people, animals, trees, buildings and other objects encompass a tiny fraction of all possible images. Appropriately enough, the images that we usually encounter are called natural images. Using a database of six million natural images, Gallant's group showed in 2009 how brain responses of volunteers to photographs they had not previously encountered could be reconstructed.

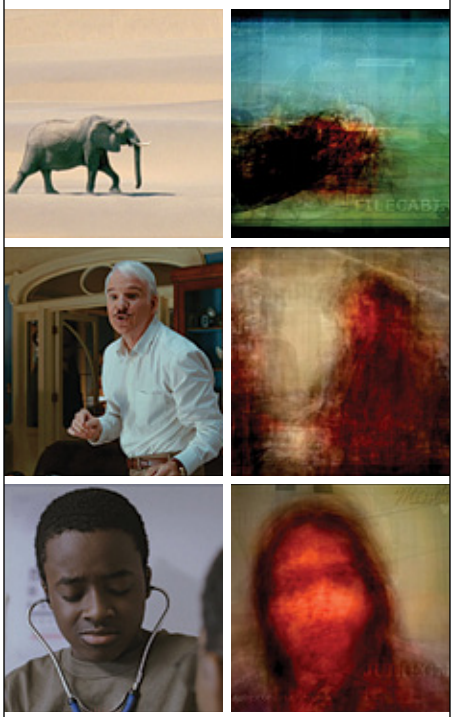
From Images to Movies

These reconstructions are surprisingly good, even though they are based on the smudged activity of hundreds of thousands of highly diverse nerve cells, each one firing to different aspects of the image—its local intensity, color, shading, texture, and so on. A further limitation I have already alluded to is the 1,000-fold mismatch between the celerity of neuronal signals and the sedate pace at which the fMRI signal rises and falls.

Yet Gallant's group fearlessly pushed on and applied Bayesian reconstruction techniques to the conceptually and computationally much more demanding problem of spatiotemporal reconstruction.

Three members of the group each watched about two hours' worth of short takes from various Hollywood movies. These data were used to train a separate encoding model for each voxel. The first part of the model consisted of a bank of neural filters. These filters are based on the cumulative research that has been conducted over two decades into the way nerve cells in the visual cortex in people and monkeys respond to seeing visual stimuli with varying positions, size, motion and speed. The second part of the model coupled these neuronal filters to the blood vasculature, describing how the neuronal activity is reflected in much slower fMRI signals.

Next, they applied the same Bayesian framework to decode fMRI signals. They used 5,000 hours' worth of short clips pulled at random from YouTube to establish a baseline of "natural movies." The same three subjects were tested by watching movies in the magnet they had not previously seen and that were not drawn from the natural movies data set. The decoder estimates the most likely clip based on the response of many voxels in the visual cortex of each volunteer. It is a very sophisticated form of hedging one's bets based on prior experience, widely used in a variety of applications—such as predicting that your credit card is being misused by somebody who has very different purchasing patterns.



The three image frames shown on the left are seen by volunteers while lying inside a magnetic scanner. Based on their brain responses, the computer reconstructs the pictures on the right.

Reconstructing the movie in the head leads to some stunning results. (I urge the reader to visit Gallant's Web site, where a movie highlights the side-by-side comparison between viewed and decoded movies.) The method is far from perfect—the reconstructed clips are slow and lack details. After all, the fMRI signal is read out only once every second, whereas the underlying movies are much more dynamic (with a 15-hertz frame rate). Yet the net result is astounding, even for an old hand like me.

What Does the Future Hold?

As our measurement tools become more precise and our algorithms more sophisticated, the quality of the reconstructed movies will improve. Indeed, it is not inconceivable that the kind of visual daydreaming we all engage in—sexual fantasies, the crux of the climb where I keep on falling, what I should have told my boss—will one day yield to these tools (provided that I engage in imagery while lying completely immobile in a magnetic scanner). And who's to say that dreams might not also be accessible to Gallant's reconstruction techniques?

Functional brain imaging is perfectly safe and requires nothing more than reclining on one's back uncomfortably for a few hours in a tight metal cylinder. Yet the fundamental spatiotemporal limits of fMRI remain. It does not access the atoms of perception, individual neurons. At the moment, only intrusive microelectrodes that are implanted in the brains of some patients, as was described in my May/June 2011 column, can access the substrate out of which our most fleeting experiences, thoughts and conscious memories arise. For now these remain safe from prying eyes. M

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MODIFIED FROM "RECONSTRUCTING VISUAL EXPERIENCES FROM BRAIN ACTIVITY EVOKED BY NATURAL MOVIES," BY SHINJI NISHIMOTO ET AL., IN *CURRENT BIOLOGY*, PUBLISHED ONLINE SEPTEMBER 22, 2011

SPECIAL REPORT **MEMORY**

Most people picture human memory as something resembling a secure metal vault into which we cram our valuable—and not so valuable—thoughts for safekeeping. The people with the biggest vaults, then, can keep the most stuff. They know the most and make the fewest mistakes.

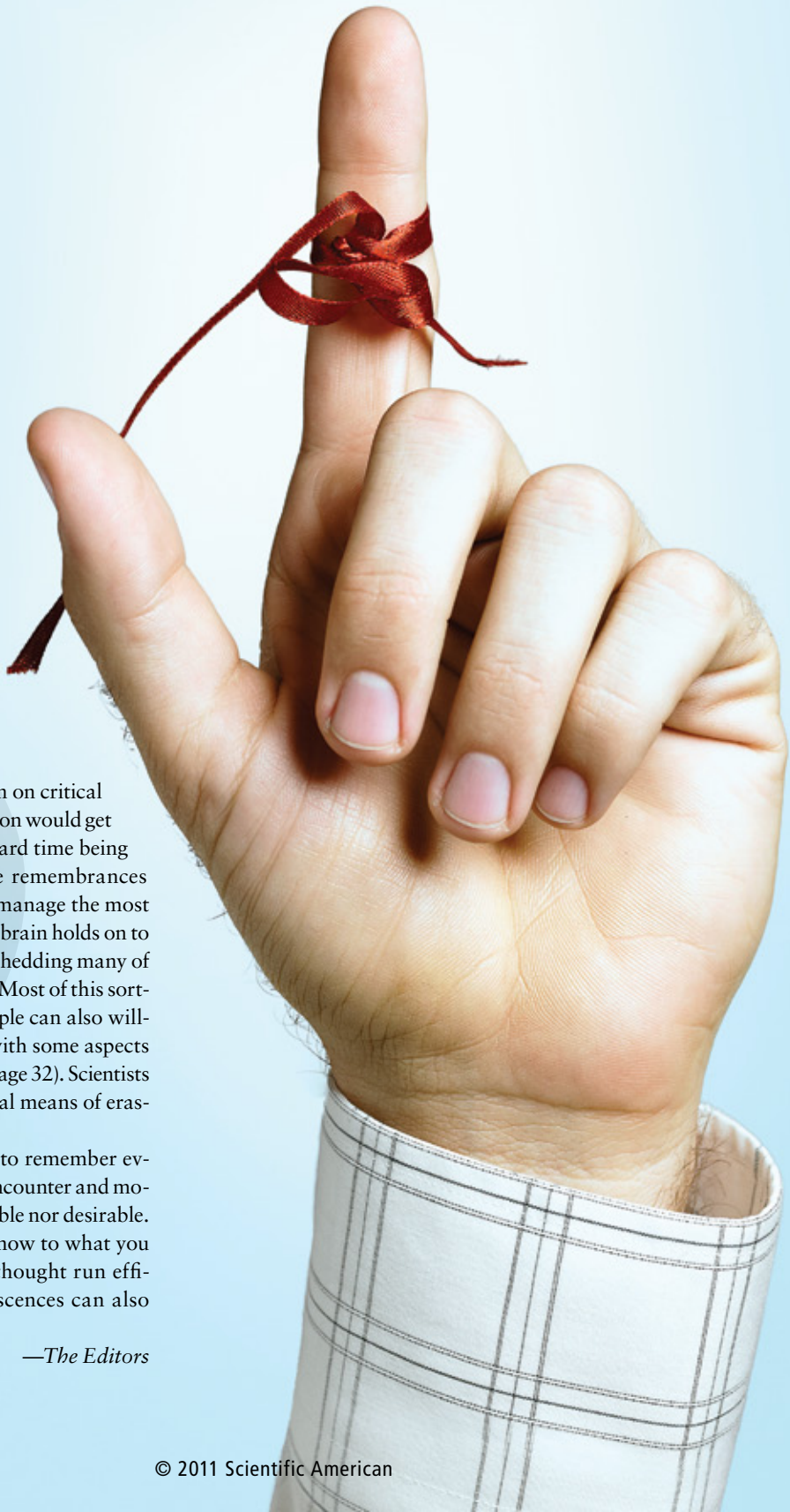
As this special report shows, however, human memory is a far cry from a passive storage unit. It behaves more like a seamstress who sews concepts from threads of vital information while snipping away extraneous material. The best memory, therefore, is not the one that holds the most data, but the one that can deftly distinguish between the pieces to keep and those to discard. In other words, the most astute individuals can both remember what is vital and, critically, forget the rest.

Without efficient forgetting, then, you would

become confused, unable to home in on critical matters because irrelevant information would get in the way. You also might have a hard time being happy, as emotions from negative remembrances might overwhelm your psyche. To manage the most vivid emotional moments, a healthy brain holds on to the gist of these recollections while shedding many of the details, as we report on page 24. Most of this sorting happens unconsciously, but people can also willfully forget, a skill that correlates with some aspects of intellect and with mental health (page 32). Scientists are also investigating pharmaceutical means of erasing bad memories (page 40).

Although people seem to want to remember everything, recording every fact you encounter and moment you experience is neither possible nor desirable. Forgetting pares down what you know to what you truly need, making the engine of thought run efficiently. Shutting out some reminiscences can also bring you considerable peace.

—The Editors



PHOTOILLUSTRATION BY AARON GOODMAN

A Feeling for the Past

Emotion engraves the brain with vivid recollections but cleverly distorts your brain's record of what really took place

By Ingfei Chen

On September 11, 2001, Elizabeth A. Phelps stepped outside her apartment in lower Manhattan and noticed a man staring toward the World Trade Center, about two miles away. Looking up, "I just saw this big, burning hole," Phelps recalls. The man told her that he had just seen a large airplane crash into one of the skyscrapers. Thinking it was a horrible accident, Phelps started walking to work, a few blocks away, for a 9 A.M. telephone meeting. By the time she reached her eighth-floor office at New York University, a second jet had struck the other tower, which collapsed after an hour. Later, she saw the remaining tower fall.

PHOTOILLUSTRATION BY AARON GOODMAN; ROBERT GIROUX *Getty Images (towers)*

Virtually no one will forget the World Trade Center—or that 9/11 happened. But our brains distort the details of that day.

BEVIS FUSHA *Redux Pictures*

Like Phelps, many Americans have searing memories of that day. In your mind's eye, you can probably relive the moment you first learned of the terrorist attacks: where you were, what you were doing, the shock or fear you experienced. Yet chances are that although they feel real and true, our memories of 9/11 are riddled with errors. "I remember all those details; I'm certain that I'm right," says Phelps, a psychologist. "But the data suggest I'm not."

Recollections of the moment we found out about surprising, traumatic public events are known as flashbulb memories, first described in 1977 by Harvard University psychologists Roger Brown and James Kulik. The idea was that emotionally intense experiences trigger your brain to perfectly record what you are hearing, seeing and feeling—like a camera snapshot when the flash goes off. Stacks of psychology and neuroscience studies indeed show that the human brain is rigged to react to a flood of feelings by activating the key regions that store memories. The brain's recordings, however, are far from flawless reproductions of the original moment.

Research from the past 25 years, including a long-term nationwide survey of 9/11 memories conducted by Phelps and her colleagues, shows that "flashbulb memory" is a misnomer. Memories forged under strong emotions distort considerably even though, paradoxically, they seem so vivid that we hold a misguided confidence in their fidelity.

Although emotion powerfully bolsters our memories of an event, it also edits and sculpts the particulars of what we recall. Such biases or imperfections might seem like a failing of the human brain, but experts note that our emotional memories serve us well most of the time—by preserving the most crucial knowledge for surviving life's challenges. Most people are oblivious to the fact that we possess a heavily edited record of the experiences that move us most. When it comes to remembering, we are more at the mercy of our emotions than we may realize.

Look Here

Amid the endless stream of everyday experience, emotion is like a blazing neon tag that alerts the brain, "Yoo-hoo, this is a moment worth remembering!"

FAST FACTS

Feeling the Moment

1» **So-called flashbulb memories actually fade considerably even though, paradoxically, they seem so vivid that we hold a misguided confidence in their fidelity.**

2» **Emotion produces a kind of tunnel memory, boosting recall of central objects but allowing people to forget surrounding details.**

3» **Putting a positive spin on a bad situation—a technique called cognitive reappraisal—can both enhance accuracy in emotional memories and diminish their negative overtones.**

Emotion is like a blazing neon tag that alerts the brain, "Yoo-hoo, this is a moment worth remembering!"

The salience of the humdrum sandwich you ate for lunch pales in comparison, consigning its memory to the dustbin. Yet emotions regulate our recall of not just our most riveting moments. Researchers now recognize that the same neural mechanisms involved in flashbulb memories underlie recollections along the continuum of human emotional experience. When people view a series of pictures or words in the laboratory, any emotionally laden content sticks in their head better than neutral information.

Memory is a three-stage process: First comes the learning or encoding of an experience; then, the storage or consolidation of that information over many hours, days and months; and last, the retrieval of that memory when you later relive it. Insights into how emotion modulates this process emerged from studies of conditioned fear responses in rats in the 1980s and 1990s by neuroscientists Joseph E. LeDoux, now at N.Y.U. [see "Mastery of Emotions," by David Dobbs; Scientific American Mind, February/March 2006], and James L. McGaugh of the University of California, Irvine, among others. Their work established that the amygdala, a structure buried deep within the brain, orchestrates the memory-boosting effects of fear.

For instance, if you suddenly glimpse a snake while walking in the woods, your amygdala instantly reacts to the snake's threatening features, explains Kevin S. LaBar, a cognitive neuroscientist at Duke University. This region signals your cortex to boost its visual and perceptual processing to confirm that the snake is real, rapidly directing your attention to it. Second, the amygdala triggers the release of stress hormones that set your heart racing and pupils dilating. Those same hormones spur the hippocampus, the memory-encoding center, to start storing or consolidating your perceptions into a neural record. Over the long run, sensory details of the memory are believed to migrate into areas of the cortex for vision, hearing and movement. Later, when you remember that snake, the amygdala and hippocampus are again involved, reigniting the emotional and sensory dimensions of that memory.

The same basic mechanisms also apply for highly arousing, positive events, LaBar explains; activity within the amygdala is associated with many kinds of emotions, not just fear. For instance, in a 2010 study LaBar and his colleagues scanned the brains of diehard college basketball fans and found that the amygdala and hippocampus lit up as the participants remembered exciting plays from a game they watched. In addition, unlike lab studies probing recollections of emotional words or images, the real-world, high-octane basketball memories also engaged social cognition areas involved in recalling situations that include social interactions, LaBar notes. Other studies show that pleasant recollections also activate the brain's reward system. Rather than being limited to a few key brain regions, emotional memory processes are "much more complex than we thought," he says.

Happy memories are susceptible to distortion, too. We tend to recall fewer perceptual details of pleasant events, however, than of troublesome ones.

DARREN McCOLLESTER *Getty Images*

Certainly Wrong

Although emotional experiences may initially be etched into memories more strongly than neutral ones, over time they twist away from reality. The first detailed evidence of the inaccurate nature of flashbulb memories emerged from surveys done after the space shuttle *Challenger* exploded in 1986. The recent analyses of 9/11 memories have further clarified what is and is not special about these intense remembrances. On September 12, 2001, Duke psychologists Jennifer M. Talarico and David C. Rubin surveyed students' memories of 9/11 and a more prosaic but notable event from the preceding weekend, such as a birthday party or study group session. In retests during the following year, accuracy of details declined equally in both types of memory. The clarity and confidence they reported in their recollections varied: the students consistently rated their memory of 9/11 as being much more

vivid than it was for the ordinary occurrences.

"They thought it was much more accurate," says Talarico, now at Lafayette College. In other words, she says, what distinguishes flashbulb memories is "this sense of enhanced vividness and inflated confidence that we have in the accuracy, this sense that I will never forget 'X.'"

A similar pattern was seen in the nationwide 9/11 memory project. Phelps and psychologist William Hirst of the New School for Social Research and their colleagues surveyed more than 3,000 volunteers in New York City, Washington, D.C., and five other cities one week after the attacks, in subsequent years and again this past summer. (Ten-year data are still being analyzed.) Compared with their initial reports, Hirst says, participants were only 63 percent correct on the when-where-how types of details about learning of the attack one year after 9/11; after that, the decline slowed. Yet they were "absolutely confident that their memory was correct," he says.

A year later people were only 63 percent correct on the when-where-how details about learning of the attack on 9/11.

Surprisingly, people were worst at describing their emotional state on 9/11, with only 42 percent of them right a year later. Initial shock may give way to sadness or frustration with time, Hirst explains, and we tend to "reconstruct our emotional past in a way that's consistent with the way we currently are emotionally reacting."

Survey takers showed better accuracy for the central facts of the terrorist event, such as the number of hijacked planes and crash sites. "Societal memory practices" such as watching media coverage and talking about 9/11 with others had a major influence. "Our memory is just not independent of the larger social context in which we exist," Hirst says.

Emotional Tunnel Vision

Our gut reactions to the world affect the brain's cataloguing efforts in several distinct ways. For one thing, emotion is selective in how it enhances memory. Experts noticed long ago the "weapon focus effect"—a witness might confidently testify to seeing the gun held by a robber and yet recall little of his face. Many other lab studies have observed the same kind of tunnel vision: individuals remember a picture of a snake in a forest better than a scene of a chipmunk set in a similar background. Although people vividly recall the snake, they tend to forget the surrounding forest, says cognitive neuroscientist Elizabeth A. Kensinger of Boston College. "Their memory for that emotional item"—the snake—"actually seems to be coming at the cost of their memory for the context."

That trade-off can partly be explained by the way an emotionally arousing object grabs your attention. Countless stimuli vie for your notice, says psychologist Mara Mather of the University of Southern California. What wins out might be something eye-catching or startling, such as a bright object flitting across the grass, or it might be something you are deliberately trying to focus on, such as a phone call, while consciously screening out distractions.

Emotions magnify this effect, intensifying the attention-snagging property of a stimulus, Mather believes. Thus, whatever dominates your mind ends up in the memory banks. That idea may help explain why, in seemingly contradictory studies, scientists have observed participants showing stronger memory for neutral details in an emotional scene. Say you are walking past a man, and a gunshot suddenly rings out from up the street. Under Mather's theory, someone who was nondescript to begin with would be even less memorable after the gunshot. Yet if you had already looked at the gentleman closely because he resembled a friend, "you would actually remember that face even better if there were a gunshot afterward," she says. The emotional nature of the situation would burn this bystander into your mind, as a kind of side effect, even though he had nothing to do with the real action.

Some research suggests that positive, highly arousing events, such as a marriage proposal or winning a prize, trigger a similar trade-off, Kensinger says. Uplifting memories, on the other hand, may differ in the type of information that is preserved, she notes, based on functional MRI studies she and her colleagues published in 2008. Whereas the scary snake-in-the-forest scenario fires up the brain's sensory processing regions, perhaps leading to a crystal-clear memory of the snake's stripes, positive excitement may instead stimulate areas in the frontal lobe that process concepts, Kensinger points out. It may, for example, train your memory toward happy thoughts about how you might spend a wad of cash that was just handed to you, rather than on what the cash looked like. "It seems like a

Emotion intensifies memory for a central, charged object in a scene at the expense of the context. In the "weapon focus effect," a witness might vividly describe a gun but be unable to picture the face of the person holding it.

GETTY IMAGES

lot of those perceptual details just are not retained with the same resolution for positive information as they are for negative information," Kensinger says. Happy memories also appear prone to distortions in accuracy and confidence—in some studies, even more so than negative recollections.

What you remember about an emotional event may also depend on your personality and age. In a 2010 study Kensinger and her colleagues found that people who reported higher everyday anxiety were more likely to exhibit the emotional memory trade-off—better retention of the main emotional features but a weaker grasp of the neutral background information—than those with less anxiety. The memories of older adults are biased in a different way; they swing toward being more positive. Mather and her associates observed in a 2003 study that after viewing a series of images ranging from, say, a cockroach on a pizza slice to the face of a smiling baby, older adults favored the happy images: half of the images the elders correctly recalled were positive and slightly more than a quarter were negative (the rest were neutral), compared with 36 percent positive, 40 percent negative for the younger participants. The effect does not seem to arise from any age-related decline in the amygdala's radar for threatening signals, Mather says. Instead older adults appear to actively manage their emotions by paying less attention to negative things.

Sleep on It

After an emotional event, increasing evidence shows, another factor has a potent hand in pruning and transforming the brain's recollection of it: sleep. "The sleeping brain seems to somehow make calculations about what to remember and what to forget," says cognitive neuroscientist Jessica D. Payne of the University of Notre Dame.

How sleep meddles with memories, however, is complex. In one study, Payne, Kensinger and their colleagues asked volunteers to look closely at chipmunk- or snake-in-the-forest types of scenes and then tested whether they recognized various components of those images after 30 minutes and again 12 hours later. One group did the experiment during the day-

(The Author)

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time, and a second group got a night of sleep before the final memory test. As expected, everyone showed enhanced memory for the emotional scenes over the neutral ones, as well as better recall for the snake but not the surrounding forest. This selectivity was even more pronounced after sleep, Payne says: whereas the memories of the entire snake scene showed some deterioration after 12 hours in those who stayed awake, the sleepers actually had better recollection of the snake and worse retention of the forest. Yet slumber offered no memory benefit for the nonemotional chipmunk scene. As Payne explains, sleep "selectively preserves only the emotional aspect of the scene."

At the University of California, Berkeley, neuroscientist Matthew P. Walker is exploring an intriguing new hypothesis that sleep also helps to soothe the sharp edges of bad memories. In particular, Walker notes that numerous studies have shown that during rapid eye movement, or "dream" sleep, the hippocampus and amygdala reactivate, yet some arousal-inducing stress hormones, particularly noradrenaline, are suppressed. The lack of those stress hormones may let the brain process emotional memories in what seems like a safe environment. During slumber, he theorizes, the brain strengthens its memory of the information within a distressing episode while "stripping away the emotional tone."

If that mechanism fails, the result could be chronic anxiety or the recurring nightmares of post-traumatic stress disorder, Walker says. Experiments by his lab also suggest that the chronic lack of sound sleep that is common in those disorders and in depression may even skew memories toward gloom, possibly perpetuating symptoms.

To keep their minds from zooming in on the most gut-wrenching element in a scene, such as a corpse, detectives keep their emotions in check and look around the area for clues.

VINCENT BESNAULT *Getty Images*

Good Enough?

What should we make of the fact that our most cherished memories may not be entirely true? Experts are quick to answer that these recollections typically do bear a hardy kernel of truth. "Our memory is good enough to get through the day," Hirst says, noting that accuracy concerns did not come up in humanity's ancient past, when neither tape recorders nor written accounts could serve as references. Yet human memory may not be sufficiently solid to offer reliable eyewitness testimony in courts, he says. There the devil may be in the details, such as whether an alleged bank robber drove off in a Honda or a Toyota SUV, and those details of a heated moment are especially fluid in memory. The challenge for psychologists, Phelps says, is to clearly define where and when people's memories of emotionally fraught incidents tend to break down. To that end, her group has unpublished results suggesting that people have more accurate recall for the place and the timing of an emotional event than for other aspects, such as who first told them about it.

An even greater mystery is why emotion infuses our memories with such a supreme yet misplaced confidence. "You can't even convince people that their memories are wrong," Phelps says. Usually when you feel certain about many facets of a run-of-the-mill recollection, you are right. With emotional events, however, your vivid memory for a few central, correct facts seems to foster the mistaken impression that it is good for all details, Phelps says.

Why this disconnect? Enhanced confidence lets you react more quickly during a similar crisis in the future, Phelps theorizes. People do not forget the gist of 9/11, and if you saw a plane flying near a sky-

The chronic lack of sound sleep that is common in anxiety and other disorders may skew memories toward gloom.

scraper you were in, she notes, "you would get out, right now."

Experts believe that human memory evolved not to provide a static, high-fidelity record of the past but to help us prepare for an unpredictable future. A malleable memory lends a powerful advantage: "You can add and change things as you need to," Payne says. That flexibility allows our brain to restructure what we have learned, make generalizations across concepts and experiences, and brainstorm new ideas.

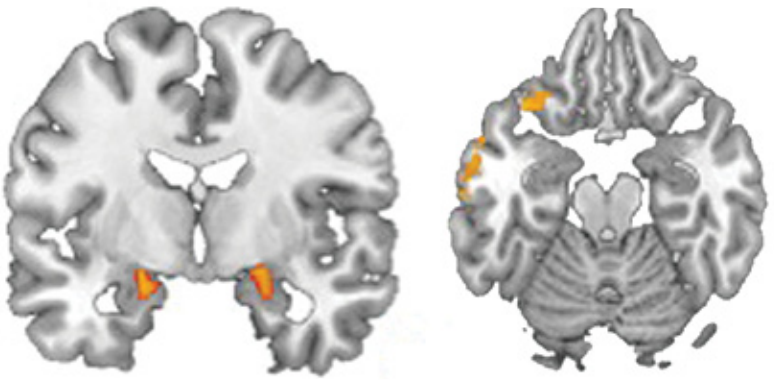
Remaking Memories

At times, though, you might prefer an accurate account over the benefits of fluid learning. By realizing that memory naturally zooms in on the most emotionally evocative aspects of an experience, you may be able to broaden your attention to override that bias. "You can make some effort to actually now focus on the nonemotional things that might be important," Phelps says. Police officers are trained in such tactics for assessing crime scenes, she notes: faced with a dead body in a motel room, homicide detectives would not only examine the corpse but also control their emotional responses to it and carefully scan around the bed or bathroom for possible clues.

Another potential way to enhance accuracy in emotional memories while also damping down their negative overtones is to put a positive spin on a bad situation—a technique called cognitive reappraisal. In a study published in 2010 LaBar, Jasmeet Pannu Hayes, a psychologist now at Boston University , and their colleagues asked people—while they were in a brain scanner—to either suppress their emotional reactions as they viewed distressing scenes or appraise them more favorably. If shown an injured man in a hospital bed, the participants could imagine that excellent care would help him heal. Compared with the suppressors, the reappraisers reported less emotional distress on seeing the unpleasant pictures and showed better memory for the images two weeks later. In the reappraisers, the hippocampus got "a double whammy" of stimulation, LaBar says: One boost came from the amygdala reacting to the negative scenes even though its response had been muted by the reappraisal process. A second communiqué came from the left inferior prefrontal cortex, which helps to process information deeply and showed greater activity in the reappraisal group [*see illustration on this page*]. (In the suppression group, the hippocampus communicated less with these other brain regions, resulting in poorer memory for the scenes.)

By using the strategy of positive thinking in a stressful circumstance, "you've lowered the emotional arousal, but you still have a good memory of it," LaBar says. Reappraisal is the basis of cognitive-behavior treatment for various psychological disorders.

The possibilities for refining our emotional memories are intriguing. Yet with the passage of time, human memory is inevitably a fragile, fading thing. Societies compensate for this frailty by holding anniversaries and memorials that revive the memory of loved ones lost—and by inventing gizmos such as tape recorders and cell-phone cameras that help us never forget. M



Thinking positively can reduce distress and sharpen memory. Activity in the amygdala, an emotion hub (*yellow spots at left*), was higher in people who passively viewed upsetting pictures than in those who appraised them positively or stifled their feelings. Part of the left inferior prefrontal cortex, an information processing region (*upper yellow spot at right*), lit up more during reappraisal than suppression. The upshot was better recall of the pictures.

FROM "STAYING COOL WHEN THINGS GET HOT: EMOTION REGULATION MODULATES NEURAL MECHANISMS OF MEMORY ENCODING," BY JASMEET PANNU HAYES ET AL., IN *FRONTIERS IN HUMAN NEUROSCIENCE*, VOL. 4, NO. 230; DECEMBER 22, 2010

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Trying to FORGET

The ability to let go of thoughts and remembrances supports a sound state of mind, a sharp intellect—and even superior memory

By Ingrid Wickelgren

Solomon Shereshevsky could recite entire speeches, word for word, after hearing them once. In minutes, he memorized complex math formulas, passages in foreign languages and tables consisting of 50 numbers or nonsense syllables. The traces of these sequences were so durably etched in his brain that he could reproduce them years later, according to Russian psychologist Alexander R. Luria, who wrote about the man he called, simply, "S" in *The Mind of a Mnemonist*.

But the weight of all the memories, piled up and overlapping in his brain, created crippling confusion. S could not fathom the meaning of a story, because the words got in the way. *"No," [S] would say. "This is too much. Each word calls up images; they collide with one another, and the result is chaos. I can't make anything out of this."* When S was asked to make decisions, as chair of a union group, he could not parse the situation as a whole, tripped up as he was on irrelevant details. He made a living performing feats of recollection.

Yet he desperately wanted to forget. In one futile attempt, he wrote down items he wanted purged from his mind and burned the paper. Although S's efforts to rein in his memory were unusually vigilant, we all need—and often struggle—to forget. "Human memory is pretty good," says cognitive neuroscientist Benjamin J. Levy of Stanford University. "The problem with our memories is not that nothing comes to mind—but that irrelevant stuff comes to mind."

The act of forgetting crafts and hones data in the brain as if carving a statue from a block of marble. It enables us to make sense of the world by clearing a path to the thoughts that are truly valuable. It also aids emotional recovery. "You want to forget embarrassing things," says cognitive neuroscientist Zara Bergström of the University of Cambridge. "Or if you argue with your partner, you want to move on." [For more on emotional memory, see "A Feeling for the Past," by Ingfei Chen, on page 24.] In recent years researchers have amassed evidence for our ability to willfully forget. They have sketched out a neural circuit underlying this skill analogous to the one that inhibits impulsive actions.

The emerging data provide the first scientific support for Sigmund Freud's controversial theory of repression, by which unwanted memories are shoved into the subconscious. The new evidence suggests that the ability to repress is quite useful. Those who cannot do this well tend to let thoughts stick in their mind. They ruminate, which can pave a path to

PHOTOILLUSTRATION BY AARON GOODMAN

Certain neurons in your brain inhibit reflexive behaviors, such as the tendency to run after a ball that you've sent flying into the street. A similar set of neurons may stop unwanted recollections from entering consciousness.

depression. Weak restraints on memory may similarly impede the emotional recovery of trauma victims. Lacking brakes on mental intrusions, individuals with attention-deficit hyperactivity disorder (ADHD) are also more likely to be among the forgetless (to coin a term). In short, memory—and forgetting—can shape your personality.

The ability to forget, however, is not immutable. If you practice applying your mental brakes, unwanted memories tend to fade. Thus, contrary to conventional wisdom, suppression therapy might someday aid in the treatment of mood and cognitive disorders. Because intentional forgetting depends on controlling which thoughts and memories seep into our awareness, the science of rejected recollections might also help scientists understand consciousness.

FAST FACTS

The Art of Forgetting

1» We can will ourselves to forget; a neural circuit like the one that inhibits actions governs the ability to reject memories we neither want nor need.

2» Emerging data provide support for Sigmund Freud's controversial theory of repression, by which unwanted memories are shoved into the subconscious.

3» The inability to forget can impede emotional recovery in trauma victims; it is also associated with attention-deficit hyperactivity disorder.

4» If you practice rebuffing recollections, you are likely to get better at it.

Cleaning the House of Memory

For most people, the concept of forgetting conjures up lost car keys, missed appointments and poor scores on exams. Worse, it augurs dementia. Psychologists traditionally shared this view, and most of them studied memory with an eye toward closing the cracks through which knowledge can slip. Even shutting out disturbing emotional memories was long considered bad form. In the early 1900s Freud proposed that people tend to block out negative recollections as a defense mechanism. According to his theory, individuals need to revisit these memories to promote psychological recovery.

An early challenge to that downbeat view of forgetting emerged in 1970, when psychologist Robert A. Bjork, now at the University of California at Los Angeles, reported that instructions to forget some learned items could enhance memory for others. Forgetting is therefore not a sign of an inferior intellect—but quite the opposite. The purpose of forgetting, he wrote, is to prevent thoughts no longer needed from interfering with the handling of current information—akin to ridding your home of extraneous objects so that you can find what you need. "When people voice complaints about their memory, they invariably assume that the problem is one of insufficient retention of information," Bjork wrote. "In a very real sense, however, the problem may be at least partly a matter of insufficient or inefficient forgetting."

Few scientists subscribed to Bjork's ideas at first, still considering forgetting to be antithetical to learning and memory. Then, in the 1990s, Bjork, along with his wife Elizabeth L. Bjork and his graduate student Michael C. Anderson, all then at U.C.L.A., identified another purpose to letting knowledge go—a phenomenon they called retrieval-induced for-

ANDREAS SCHLEGEL Getty Images

getting. They found that deliberately revisiting certain stored information impedes later recall of material very similar to it. The process is adaptive because it eliminates or tones down memories that are most likely to obstruct more important thoughts. It enables the route you drive to a friend's new house, for example, to overshadow the way you went to her previous abode. "If you forget things, there is less interference with the stuff you do want to keep," says psychologist John Jonides of the University of Michigan at Ann Arbor. "That is a big boost to memory."

This boost is thought to rely on the brain's prefrontal cortex, which sits roughly behind the forehead. The prefrontal cortex is home to the brain's so-called executive functions, which include planning, calculating and reasoning, as well as control over our impulses. Many areas of the prefrontal cortex are thought to be inhibitory; they calm the responses of neurons in other parts of the brain. When we feel like lashing out at a spouse for coming home late or leaving the house a mess, for example, cells in these regions (if they are working that day) keep us from raising our voice. More prosaically, they can stop us from reflexively running after a ball that has been knocked into a busy street.

Researchers surmised that some of these same inhibitory neurons could work on memory. In the case of retrieval-induced forgetting, the inhibition occurs unintentionally, beneath our awareness. But about 10 years ago Anderson, then a cognitive psychologist at the University of Oregon, wondered if people could exert conscious control over their memories. Can we will ourselves to forget? After all, we often want to forget things, whether for emotional or intellectual reasons.

Psychologists have now found scientific support for **Sigmund Freud's controversial theory of repression.**

Repression Revisited

To test his idea, Anderson constructed a memory version of a task called go/no-go that is used to assess a person's ability to inhibit actions. In a study published in 2001 Anderson and his student Collin Green, now at the NASA Ames Research Center, gave 32 college students what they called a think/no-think task. The students learned 40 word pairs such as ordeal-roach, with the first word serving as a cue for the second. Next they presented the cues and asked participants either to think about and say the word that went with it or to suppress (not think about) the associated word.

Suppression seemed to work. The students even recalled fewer of the suppressed word associations than the "baseline" words—ones they learned but neither practiced nor inhibited. And the more times the students tried to block the memory of a word pair, the worse that memory was; that is, the more they *tried* to forget the more they *did* forget. In contrast, their recollection for a word pair improved as they recited it repeatedly. When the researchers gave the students new cues for the same words, the students again had the most trouble coming up with the suppressed words, showing that they had forgotten those words. These findings suggest that the brain can tamp down unwanted memories, as Freud suggested. Although Freud thought repressed memories came back to haunt us, the new data indicate that people can make such recollections fade into the background (although for how long is still unclear). Doing so may therefore be an important way of regulating our emotions and thoughts. Letting miscellaneous notions wander into our mind in response to reminders is a cognitive version of a motor reflex, says Anderson, who is now at the Medical Research Council's Cognition and Brain Sciences Unit in Cambridge, England. "We don't always want to act reflexively," he says. "That's what makes us human."

Machinery of Restraint

Within a few years Anderson and others had sketched out the brain regions undergirding this memory control. In 2004 he, along with psychologist John Gabrieli, then at Stanford, and their colleagues, used functional MRI to scan the brains of participants as they performed the think/no-think task. By looking at the contrast between scans generated when a person was supposed to remember the words with those from when they tried to forget, the researchers associated memory suppression with greater activity in two regions of the prefrontal cor-

(The Author)

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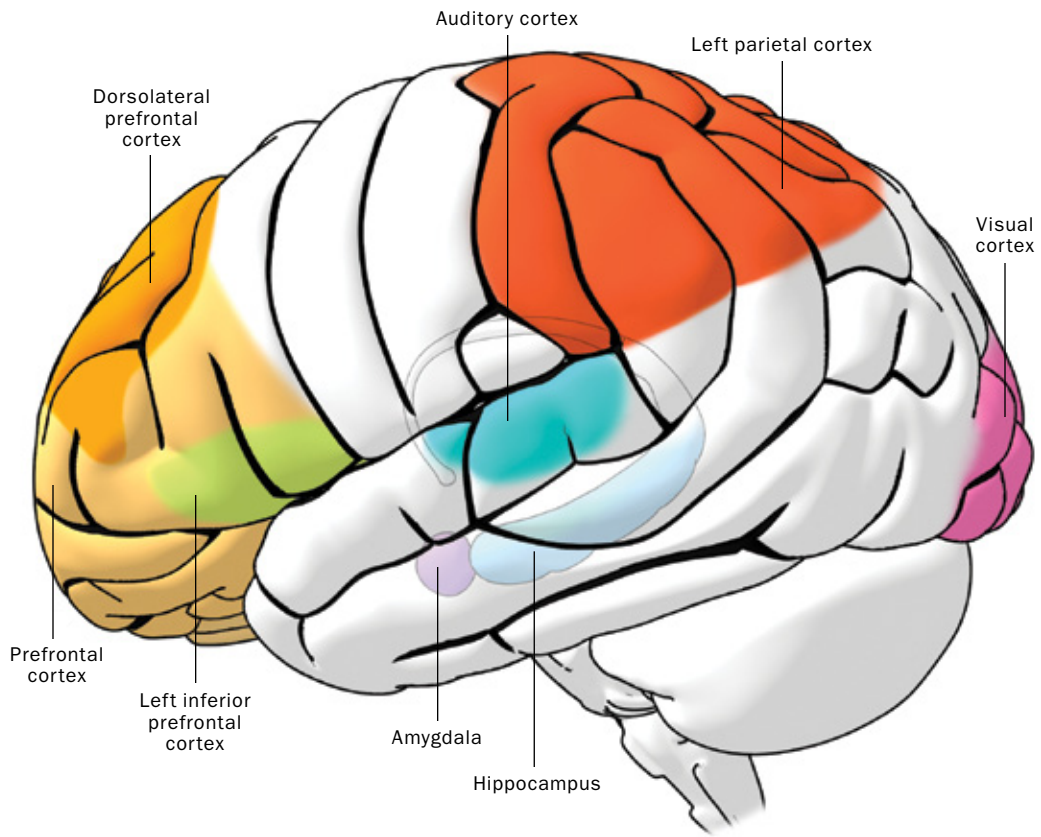
tex—the aforementioned region devoted to planning and oversight—and diminished activity in the hippocampus, an area responsible for both binding components of a memory together and reactivating it [see "Making Connections," by Anthony J. Greene; Scientific American Mind, July/August 2010].

Items that were later remembered produced more activity in the hippocampus than did items that would be forgotten, a pattern that thus forecast which pairs were successfully suppressed. Meanwhile the engagement of the prefrontal cortex foretold the likelihood of forgetting in an individual: more activation meant more inhibitory power.

Cognitive neuroscientist Brendan Depue of the University of Colorado at Boulder and his colleagues decided to examine how emotion might affect those results. In a 2006 study Depue's team tested subjects on their ability to learn, remember and suppress associations between faces with neutral expressions and several other stimuli—words that are negative (such as "deformed") or neutral ("lantern," for example) or pictures that were either unpleasant or unemotional. They found not only that suppression worked for this task but that it is even stronger if the stimuli are negative, hinting that people may have more power over emotional memories than neutral ones. Moreover, when individuals are exerting this control, Depue and his colleagues reported in 2007, sensory parts of the brain, including the visual cortex, first go silent, as if the brain is trying to rid itself of recollected imagery. As people continue to practice holding back a thought, both the hippocampus and the amygdala, a key player in processing emotions, quiet down. Once the visions of the experience fade, Depue theorizes, the brain tries to minimize the emotions still clinging to it and strives to degrade

Forgetting to Remember

A patchwork of brain areas play roles in forgetting—and remembering. In the prefrontal cortex, the dorsolateral region governs memory suppression, whereas the left inferior part aids in the construction of stronger emotional memories. The hippocampus is the hub of memory formation. It is accompanied by its sidekick, the amygdala, when feelings are involved. Visual and auditory regions go silent when the mind is shutting down recollections. An analogous quieting occurs over the parietal cortex, as evidenced by a shrinking of the brain-wave signal detected there.



GEORGE RETSECK

the memory as a whole. The region running the show was, as usual, the prefrontal cortex.

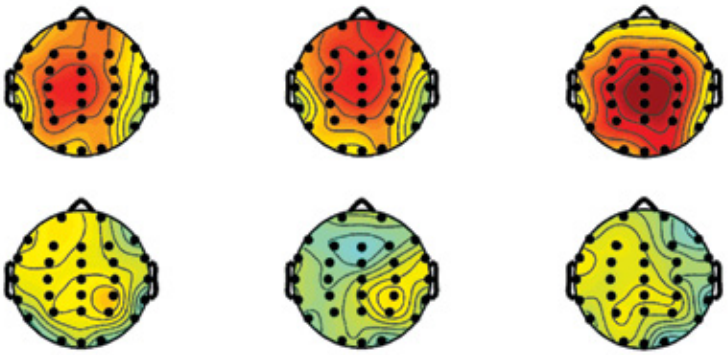
Bergström and her colleagues have now identified a brain signal that marks the moment of forgetting. Using electroencephalography, her team taps into the electrical fields generated by neurons through electrodes affixed to the scalp. Changes in these fields instantaneously reflect new cognitive events. One wave of activity detected near the crown of the head is related to the amount of recollected information, according to Bergström's latest data. The larger the signal, the more detailed the memory. In a study published in 2007 Bergström and her colleagues saw this signal shrink within half a second of an attempt to suppress a memory that had been elicited by a cue. In 2009 the same group reported that only concerted efforts to suppress a memory, without thinking about anything else, provoked this electrical sign of forgetting. "The signal related to the recollection was reduced to the point where it looked like they were not remembering much at all," Bergström says.

When people instead used thought substitution—a technique that involves replacing the idea you want to stop with another—the memory signal did not shrink. Although the participants doing such switches did forget some of the word associations they had learned, their forgetting was less complete, suggesting it occurred by a different mechanism, Bergström says [*see illustration on this page*].

Too Much Memory

Forgetting does not come easily to everyone. The best performers in Anderson's experiments forgot up to 60 percent of the material they tried to block—an impressive feat for just a little more than one minute of practice. Mild versions of Shereshevsky, in contrast, strained to erase the traces of the word pairs, in some cases recalling them *better* after many suppression attempts. "There's a huge range in how effective people are at forgetting," Levy says.

This skill, or lack of it, has ripple effects on personality. If you cannot shake negative memories, for example, you might be easily sucked into a bad mood. Although the inability to forget does not cause depression, research shows that depressed patients have difficulty putting aside dark thoughts.



Maps of the brain show voltage differences over the crown of the head (parietal cortex) about half a second after people try to suppress memories (*top row*) but not following attempts to substitute one thought for another (*bottom*). The colors represent the difference in voltage between trials in which a word was later forgotten and those in which it was remembered. A positive difference (*red*) shows that forgetting follows a brain potential that was reduced relative to remembering. Yellow and greenish hues indicate little or no discrepancy between the two.

In one experiment, published in 2003, psychologist Paula T. Hertel of Trinity University in San Antonio and Melissa Gerstle, now at the Texas Children's Hospital and Baylor College of Medicine, found that depressed students recalled many more words they had practiced suppressing than other students did. The students who had the most trouble forgetting scored the highest on measures of rumination—which is the tendency to dwell on a concern—and the frequency of unwanted thoughts.

Poor memory control can also accompany other cognitive problems—inattention, in particular. In 2010 Depue's group reported that people with ADHD had more trouble forgetting face-picture pairs in a think/no-think task than individuals did without the disorder. The more severe a person's ADHD, the more difficulty he or she had on this task. A distinct pattern of brain activation seemed to underlie these deficits: the prefrontal cortex was less active during the suppression tasks in the patients than in the others. Even after 10 to 12 attempts to block an association, the hippocampus and amygdala, which together record emotional memories, showed no signs of shutdown in those with ADHD. Thus, ADHD seems to involve diminished control over memory as well as actions. This shortfall opens the door to distracting thoughts that can disrupt efforts to concentrate.

"There's a huge range in how effective people are at forgetting," says one cognitive neuroscientist.

FROM "ERP AND BEHAVIOURAL EVIDENCE FOR DIRECT SUPPRESSION OF UNWANTED MEMORIES," BY ZARA M. BERGSTRÖM ET AL., IN *NEUROIMAGE*, VOL. 48, NO. 4; DECEMBER 2009. REPRINTED WITH PERMISSION FROM ELSEVIER. (*EEG*)

Perhaps not surprisingly, those with good executive function excel at memory suppression. One measure of executive function is so-called working memory, a mental workspace that enables you to hold and manipulate information in your mind to, say, read or perform mental calculations. In two recent experiments, not yet published, Anderson and Ted Bell, a psychologist at the University of Oregon, tested people's working memory by asking them to hold an ever lengthening list of words in their mind while performing mental calculations. The individuals who could remember the most words were also the best forgetters in a think/no-think task. "Keeping things in mind is related to keeping things out of mind," Anderson quips.

For the average person, the ability to forget goes up and down over the years just as executive function does. In 2009 Anderson, neuroscientist Pedro M. Paz-Alonso of the University of California, Berkeley, and their colleagues reported that memory suppression improves between age eight and 12, when it approaches the level seen in young adults. At the end of life, forgetting again becomes more difficult. In a study published in 2011 Anderson and his colleagues discovered that elderly adults had more trouble than those aged 18 to 25 keeping an experience out of consciousness when reminded of it. "Kids and older adults have a hard time getting rid of this stuff," says psychologist Karl-Heinz Bäuml of Regensburg University in Germany. As a result, Bäuml surmises, both age groups may have particular problems recovering from unpleasantness in life.

Eternal Sunshine

In the 2004 movie *Eternal Sunshine of the Spotless Mind*, Clementine (Kate Winslet) has a falling-out with her boyfriend, Joel (Jim Carrey), so she has him erased from her mind. As the doctor, Howard (Tom Wilkinson), explains to Joel, "She was not happy; she wanted to move on. We provide that possibility." Howard's services are summed up neatly by his adoring assistant: "Adults are this mess of sadness, phobias … Howard just makes it all go away," she says.

If only. Researchers are investigating pharmaceutical ways of finessing forgetting, but no foolproof medical means for erasing troublesome memories is on the horizon [see "Totaling Recall," by Adam Piore, on page 40]. Nevertheless, people might be coached to forget.

In psychology experiments, 10 to 20 attempts to block a memory reliably lead to forgetting in many people, Bäuml says. Thus, in theory, you could bury a recollection by shutting it out every day for a month. Bäuml has also found a way to enhance the effect. In 2010 he and his colleagues gave college students performing the think/no-think task one second of advance notice about having to suppress (or recall) a word they had associated with a face. The warning improved performance: the students who could prepare to apply their mental brakes forgot more of those words than did those who received the cue at the same time as the instruction to suppress. So when you have to enter a situation that is likely to trigger difficult memories, think about the need to put these out of mind ahead of time, and you may find yourself better able to do so.

Practicing suppression over years might also make you better at it. Anderson, along with his graduate student Justin Hulbert and neuroscientist Brice Kuhl of Yale University, showed that college students who had experienced serious trauma—say, from the death of a loved one, a rape or a natural disaster—were consistently better at blocking words when reminded of them than were undergraduates who had suffered little. Therefore, a long-term effort to keep a bad memory out of mind may hone your inhibitory skills. Of course, trauma victims who make it to college may have good executive control to begin with.

Indeed, because of such individual differences, suppression alone might not work well for everyone. In a 2009 study Hertel, Jutta Joormann of the University of Miami and their colleagues had adults who were depressed memorize unrelated pairs of nouns, each consisting of an emotionally neutral word plus either a positive or negative term—mushroom-hostage, for example, or curtain-humor. They then practiced the positive pairs and suppressed the negative ones, although some of the subjects used a thought-substitution strategy in which they replaced the target word with a different one. When they were tested on the material, the depressed people who used suppression did not forget any more of the negative words than they did the words they did not try to

In theory, you could bury an unwanted recollection by shutting it out every day for a month.

SIMON SONGHURST *Getty Images*

Intentional memory suppression may not work for everyone. But someday it might form the basis of a new psychotherapy for post-traumatic stress and other mood disorders.

suppress. In contrast, the patients who used thought substitution saw about a 25 percent drop in recall after just two opportunities to practice the technique. The results suggest that those who are depressed cannot just push away unwanted memories; they may need to actively replace them.

Some psychologists advocate neither method. Another way to forget, says cognitive psychologist Tracy Tomlinson of the University of Maryland, is simply to do something distracting at the moment of recall. In a study published in 2009 Tomlinson and her colleagues found that individuals who pressed the enter key whenever the cue for a word appeared forgot just as many words as those who tried to mentally block the words from coming to mind. "People don't have to actively search for a memory and then stomp it out," Tomlinson says. "Action interferes with recollection."

None of these methods of personal mind control has been refined for clinical use. Clearly, people can forget upsetting words or terrified faces, but their ability to shut out deeply personal emotional memories, such as those of sexual abuse, remains uncertain, Tomlinson says. Nevertheless, researchers hope to parlay some kind of forgetting into treatments for mood disorders, including depression and post-traumatic stress, and perhaps obsessive-compulsive disorder.

Some situations should not simply be put out of mind, of course, because they could recur or may need to be assessed for other reasons. Even here, forgetting may play a role. In helping patients reinterpret an experience, therapists may inadvertently induce memory loss by emphasizing the event's uplifting aspects. In so doing, they may change the relative accessibility of positive and negative memories, such that the uplifting ones spring to mind more readily. In this way, forgetting in its many guises may be the secret agent behind much of mental health.

It also may help crack the code of consciousness. The ingredients of conscious awareness come not only from our senses, which monitor the external world, but also from our thoughts and memories, of which we can also be aware—or unaware. Knowing how people willfully exclude such internal abstractions from their minds could teach us about how consciousness works in general, Anderson says. "What is there for us other than our moment-to-moment conscious experience?" he asks. "If we can understand that, we will touch what is fundamental to people." M

(Further Reading)

- **Suppressing Unwanted Memories.** Michael C. Anderson and Benjamin J. Levy in *Current Directions in Psychological Science,* Vol. 18, No. 4, pages 189–194; August 2009.
- **Anticipation Boosts Forgetting of Voluntarily Suppressed Memories.** Simon Hanslmayr, Philipp Leipold and Karl-Heinz Bäuml in *Memory,* Vol. 18, No. 3, pages 252–257; April 2010.
- **Inhibitory Control of Memory Retrieval and Motor Processing Associated with the Right Lateral Prefrontal Cortex: Evidence from Deficits in Individuals with ADHD.** B. E. Depue, G. C. Burgess, E. G. Willcutt, L. Ruzic and M. T. Banich in *Neuropsychologia,* Vol. 48, No. 13, pages 3909–3917; November 2010.
- **Interference Resolution in Major Depression.** Jutta Joormann, Derek Evan Nee, Marc G. Berman, John Jonides and Ian H. Gotlib in *Cognitive, Affective and Behavioral Neuroscience,* Vol. 10, No. 1, pages 21–33; March 2010.
- **Intentional Suppression of Unwanted Memories Grows More Difficult as We Age.** M. C. Anderson, J. Reinholz, B. A. Kuhl and U. Mayr in *Psychology and Aging,* Vol. 26, No. 2, pages 397–405; June 2011.

Totaling Recall

Scientists can put memories in a precarious state—and manipulate, or even erase, them

By Adam Piore

Joël Coutu knelt on the cold cement floor of the pet supply store he managed in Montreal, his wrists bound behind him with telephone wire. He could feel the barrel of a pistol pressed against the back of his neck. "You're lying!" the gunman screamed. "And I am going to blow your head off."

He and another attacker had herded Coutu and a young cashier into the back room and demanded that he unlock the safe. When he told them he did not have the key, they became enraged. They ripped out all the wires of the fax and telephones in his office and tossed the contents of his desk drawers. Now they were getting ready to execute him. "Go ahead and pop him," he heard one of them tell the other. "Blow his head off.'"

Coutu had just enough time to turn to his co-worker and ask her to tell his girlfriend that he loved her before the gunman smacked him with the butt of the weapon and sent him sprawling. Lying face-down, Coutu watched his blood pooling around him and waited for the coup de grâce. Then, suddenly, the front door of the store slammed. The assailants had fled, empty-handed.

Yet Coutu's ordeal was just beginning. For years he would be tormented by violent nightmares, panic attacks brought on by the mere hint of aggression around him, and severe depression—signs of post-traumatic stress disorder (PTSD). His girlfriend moved out. He retreated from his friends and left his job.

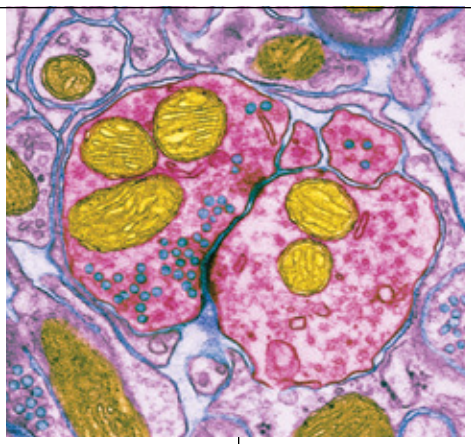
Then, one day in 2009, he saw an advertisement in a local newspaper for a trial of an experimental therapy run by Alain Brunet, a McGill University psychiatrist. Brunet suggested something radical: he wanted to erase portions of Coutu's memory.

For decades scientists believed that long-term memories were immutable—unstable for a few hours and then etched into the brain for good. Research now suggests that recalling a memory causes it to revert temporarily to an insecure state, in which the recollection can be added to, modified, even erased. "Memory is more dynamic, more fluid and malleable than we thought," says neuroscientist Daniela Schiller of Mount Sinai School of Medicine.

That idea, brought to the fore about a decade ago, has opened up a new controversial research area exploring the possibility of deleting, or at least muting, parts of human memory with drugs or targeted therapies. Some experts have found that a drug used to treat high blood pressure works to unseat recollections; others are testing novel biochemical means or behavioral interventions to interfere with unwanted remembrances. [For more on psychological forgetting strategies, see "Trying to Forget," by Ingrid Wickelgren, on page 32.]

Although scientists and ethicists worry that such drugs might be abused or have unsettling side effects, these treatments could also liberate individuals from experiences that haunt them—including a traumatic event, such as that experienced by Coutu—and the emotions that linger, such as the agony from the death of a loved one or the crippling apprehension from a car accident or sports injury. "Imagine a high jumper who fell during the Olympics," says neuroscientist Karim Nader of McGill. "They may have a lot of anxiety associated with jumping, and it could severely affect their future performance. If we can make these drugs work, you could help them, too—or anyone with anxiety that is proving a problem."

PHOTOILLUSTRATION BY AARON GOODMAN



When memories form, a chain of molecular events remodels some of the junctions, or synapses, between neurons (*pink*). Here one neuron is poised to release neurotransmitters from vesicles (*blue*) into the tiny gap between the cells.

Window of Vulnerability

To create, or consolidate, stable long-term memories, the brain must synthesize specific proteins in the hours after events occur. Those proteins are part of a cascade of chemical processes that remodel some of the tiny junctions, or synapses, between brain cells to make these cells communicate more efficiently. The construction process often includes the production of *more* synapses, which further facilitates neuronal chatter.

A decade ago most memory researchers believed these synaptic connections were extremely stable and resistant to degradation. They might fade with time, but they could not be changed or erased. Yet Nader, as a 33-year-old postdoctoral student at New York University back in 1999, was new enough to question that dogma. After attending a speech on memory delivered by Nobel laureate Eric R. Kandel, a Columbia University neuroscientist, Nader wondered exactly what happens when we recall an event. To do so, it seemed to him, you would have to take the memory *out* of storage. What if you added new information or blocked the chemical processes needed to put that memory back?

To find out, Nader and his colleagues created the kind of searing emotional memory that should have been permanent and immutable. He placed a rat in a cage and played a tone while delivering a shock through the metal floor. Soon all Nader had to do was play the sound, and the rat would freeze in terror. The two stimuli, convention held, had been permanently connected.

Fourteen days later the researchers played the tone and simultaneously injected a drug that blocks protein synthesis into the rat's amygdala, an emotion hub in the brain with an important role in establishing emotionally rich memories. Nader's intent was to see if the drug would interfere with the memory's return to storage. The strategy worked. In subsequent trials, the animal no longer froze at the sound. It had forgotten the meaning of the tone and therefore had been liberated from its trauma.

The experiment provided powerful support for a theory called reconsolidation that was first floated back in the 1960s but largely abandoned because of lack of evidence. It holds that reminding a person or animal of something makes that memory temporarily unstable. During a brief window before the memory is "reconsolidated," it is susceptible to perturbation. "We used to think the memories we had were pictures of the original event. Now we know that it is the last version of the memory because each time we retrieve it, it changes a little bit," Schiller says.

Shutting Off the Alarm

Nader's findings were a revelation to Brunet. The Montreal-based psychiatrist had already been experimenting with ways to prevent the initial consolidation of traumatic memories as a preventive measure against PTSD. Brunet, along with Roger K. Pitman of Harvard University, had drawn his inspiration from a series of groundbreaking experiments conducted by James L. McGaugh and his colleagues at the University of California, Irvine, in the 1990s. McGaugh had demonstrated that a drug called propranolol, a so-called beta blocker used to treat high blood pressure and anxiety, could also weaken new memories.

Propranolol interferes with a key signaling agent that normally augments memory formation in response to an emotional event. [For more on emotional memory, see "A Feeling for the Past," by Ingfei Chen, on page 24.] Anytime we get emotionally aroused, the adrenal gland releases stress hormones, which trigger the release of a chemical in the brain called norepinephrine. This neurotransmitter binds to receptors in the amygdala, which in turn discharges a flood of chemicals that signal the rest of the brain to encode the memory. Propranolol binds to, and blocks, those receptors. McGaugh showed he could inhibit typical memory formation by administering propranolol, which he thinks interferes with the action of norepinephrine—thus preventing

FAST FACTS

Messing with Memories

1» **Scientists once believed that long-term memories were immutable. Research now suggests that reminding a person of something makes that recollection temporarily revert to an insecure state, in which it can be modified, even erased.**

2» **Deleting, or at least muting, parts of human memory with drugs or targeted therapies might help people recover from trauma or anxiety.**

3» **Promising approaches for altering remembrances include a drug used to treat high blood pressure and chemicals that block a newly discovered enzyme that helps recollections persist.**

THOMAS DEERINCK *Photo Researchers, Inc.*

ERIK ISAKSON *Corbis*

Drugs that could tone down or erase memories might squelch anxiety in skiers and other athletes who have had frightening falls or crashes while practicing their sport.

the memory-boosting signal from ever going out.

Pitman and Brunet immediately recognized the potential for treating patients who had been exposed to trauma—triggering what Brunet calls "pathological remembrances." In 2002 and 2003 teams led first by Pitman and then by Brunet administered propranolol to trauma victims who came through emergency rooms in Boston and in Lille, France. Both research groups demonstrated that administering the drug was far more effective at reducing the likelihood the participants would develop PTSD than a placebo was.

Brunet and Pitman were both excited by the effects of the drug. Yet the limitations of the therapy were clear. The procedure would help patients only during the brief window before the long-term memory had consolidated, within hours of the initial event. By definition, PTSD does not set in until at least six months later.

Nader's findings offered new hope. They showed that established memories could be made labile again just by taking them out of storage. So, in 2005, Nader, Brunet and Pitman joined forces to test whether propranolol might also be able to tweak older memories. The researchers asked 19 patients suffering from chronic PTSD to recall their trauma. They gave half of them propranolol and the other half a sugar pill. A week later Brunet monitored the physiological response of the patients as they listened to an audio account of their event. Those who had received the beta blocker still retained a memory of the factual details but were significantly less aroused than those given the dummy drug. A few theories attempt to explain propranolol's action. As with the initial trauma, recalling an agonizing memory releases stress hormones, which may well be involved in reconsolidating the memory afterward. One possibility is that propranolol blunts the action of norepinephrine then, too. Alternatively, the drug might be inhibiting the protein synthesis needed to put emotional memories back into storage.

Either way the initial evidence for propranolol's effects, published in 2008, led to the larger study for which Coutu volunteered. Once a week for six weeks, Coutu took propranolol and read a one-page description of the armed robbery out loud. The task was so unsettling that Coutu considered dropping out after just one session. That night he was terrorized by nightmares. Halfway through the fifth session, however, something remarkable happened. "I will never forget it," he says. "I'm reading the one page, and it's like I have no more attachment to the story—like I am reading a novel or watching a movie. I started to smile, I was so excited."

Brunet published the results of his study, which

"Now we know that … each time we retrieve [a memory], it changes a little bit," says one neuroscientist.

(The Author)

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included 66 patients in Boston, France and Montreal, this past August. On average, physiological symptoms of fear such as a racing heart and sweating diminished by 50 percent for the 40 PTSD patients who took propranolol, compared with a 7 percent decrease for the 26 patients who did not take the drug. After the experiment, Brunet claims, roughly three in four propranolol patients were so improved they no longer met the criteria for PTSD.

New Knowledge

Yet propranolol may not offer a foolproof way to forget. Neuroscientist Elizabeth A. Phelps of N.Y.U. and her colleagues spent several years attempting to erase fear memories in mentally healthy people using propranolol. They found that the drug could only temporarily expunge a learned association between a visual stimulus (a colored square) and a shock. The fear later returned as if the therapy had never been applied at all.

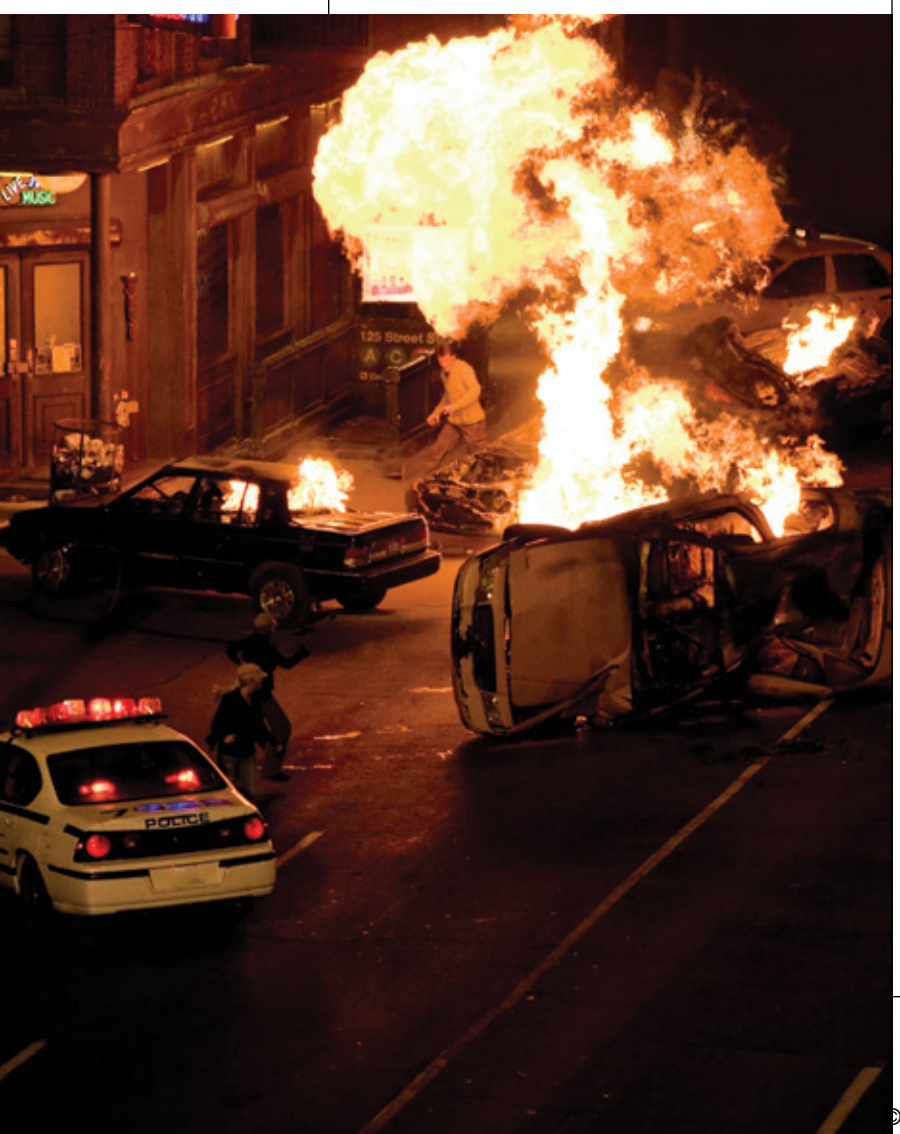
Phelps believes the propranolol failed because her subjects still knew that the colored squares were associated with the shocks—and that this conscious memory generated a fear response even after the emotional record of the initial event was erased. Exactly why the drug worked for trauma victims is unclear, but Brunet says their memories are starkly different from the associations Phelps studied. "We are dealing with people with PTSD, and her subjects are dealing with a very simple task using squares and triangles," he says.

In a study published in 2010 Phelps and Schiller demonstrated a method Phelps believes eliminates the potential interference from overt knowledge. Instead of simply sending subjects home after the visual reminder of the shock, the researchers added an experience designed to modify both the conscious and emotional aspects of the memory.

After showing volunteers a picture of the square, Schiller and Phelps waited for a variable period, then delivered "extinction training," a kind of behavioral therapy intended to overwrite the dreaded association with one that is benign. In this case, the researchers exposed the volunteers to images of the colored squares, but this time they did not deliver a shock so that these individuals would think of the images as "safe" again. The timing of this extinction training was key. Previous research held that the initial reminder, the square, would spark chemical processes that would render the memory of the shock temporarily vulnerable to modification or erasure while the memory was being reconsolidated. This so-called reconsolidation window would close once those processes were complete.

Some volunteers viewed the square 10 minutes before receiving this extinction training, a time point within the reconsolidation window. Others saw the square six hours before the extinction training—safely outside that window. A third group did not see the square prior to extinction training.

All three groups returned to the lab on a third night and were presented with pictures of the squares as researchers monitored their fear response. The response virtually disappeared in those who had received the extinction training during the reconsolidation window, whereas it returned for those who had not, providing evidence that *human* memories are malleable during this window and can be blunted without drugs. In fact, altering memory with new information in this manner might be especially effective because it adds to conscious knowledge, rather than just altering an instinctive fear memory—a strategy that might not work in the long run. (Other forms of behavioral therapy, such as memory suppression, may also work most effectively during recall, within the reconsolidation window.)



One type of blood pressure medication has already shown some efficacy in blunting the memories of people haunted by traumatic experiences. Novel remedies for getting rid of recollections are under development.

GETTY IMAGES

Chemical Intervention

If you asked one of Phelps and Schiller's volunteers what happened the first night of the trial, they would very likely be able to tell you about the shocks, even if they no longer linked them with the squares. The same holds for the propranolol-taking trauma victims. But what if we could erase those memory traces altogether?

Neuroscientist Todd C. Sacktor of S.U.N.Y. Downstate Medical Center in Brooklyn is developing a compound that would do just that. In 1990 Sacktor and his colleagues discovered an enzyme known as protein kinase M-zeta (PKMzeta) they suspected might play a role in long-term memory. Not only was the enzyme present in the appropriate regions of the brain, but it also had chemical properties that scientists thought were ideally suited to supporting the maintenance of such neural traces.

In 2006 Sacktor's team confirmed its hunch. The researchers trained a rat to avoid an area of a room where it received an electric shock. Then they waited a day and injected a drug that inhibited PKMzeta into the hippocampus, where the memory was presumably stored. When they put the rat back in the room, it could not remember what area to avoid. Blocking the actions of PKMzeta had wiped out the rat's memory of the event, proving the enzyme had a role in maintaining the memory. This past March, Sacktor and his colleagues reported the same effect with a mutation that crippled PKMzeta. They also did the reverse and enhanced memory in rats with a genetic manipulation that caused the animals to produce additional copies of the enzyme.

Meanwhile Sacktor's team had figured out how the enzyme worked. It catalyzes a reaction that enables the transport of key proteins to the synapses. These proteins respond to the neurotransmitter glutamate, allowing a neuron to detect the firing of a neighboring cell by its resulting release of glutamate. The upshot is effective information transfer.

A drug that shuts down PKMzeta, however, is like a "nuclear bomb," Nader says; it obliterates all memory, not just the recollections you want to detonate. Yet Sacktor may have found a way around this problem. Every time a memory is pulled out of storage, he believes, the brain breaks down the PKMzeta connected to that memory. To put the memory back, he posits, the brain must create the enzyme anew. Sacktor has developed a drug that, in unpublished experiments, blocks the synthesis of *new* PKMzeta in rats for about two hours. In theory, then, a person could selectively shut out troublesome memories by recalling them, making them active and then taking this drug, which would stop the brain from restocking them.

If the drug works as Sacktor imagines—a big "if" at the moment—it promises to be more powerful than propranolol. "With propranolol, the problem is trying to get that very potent and effective erasure," Sacktor says. "That is not the issue with PKMzeta."

Bioethicists such as Paul Root Wolpe of Emory University worry about such strong medicine for the mind. "Memory is such a crucial part of what makes us who we are that we have to be extremely cautious about changing or erasing [memories]," Wolpe says. "To what degree will we use this technology in ways that threaten selfhood and personality?" He also frets that people with sinister motives could abuse a potion that makes others forget—enabling an intelligence officer to get away with torture, say, or a parent with the abuse of a child.

Yet the terror Coutu, and others like him, endured is arguably *not* a critical part of who he is. For Coutu, the memory of his attackers seemed to accomplish quite the opposite: it cracked his sense of self. Only calibrating that recollection, in fact, could enable him to reassemble the person he had been—and the delightfully ordinary life he once led. M

Blocking the actions of the enzyme PKMzeta in rats wiped out the animals' recollections of the event.

(Further Reading)

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- **Preventing the Return of Fear in Humans Using Reconsolidation Update Mechanisms.** Daniela Schiller, Marie-H. Monfils, Candace M. Raio, David C. Johnson, Joseph E. LeDoux and Elizabeth A. Phelps in *Nature,* Vol. 463, pages 49–53; January 7, 2010.
- **Does Reconsolidation Occur in Humans?** Daniela Schiller and Elizabeth A. Phelps in *Frontiers in Behavioral Neuroscience,* Vol. 5, Article 24. Published online May 17, 2011.
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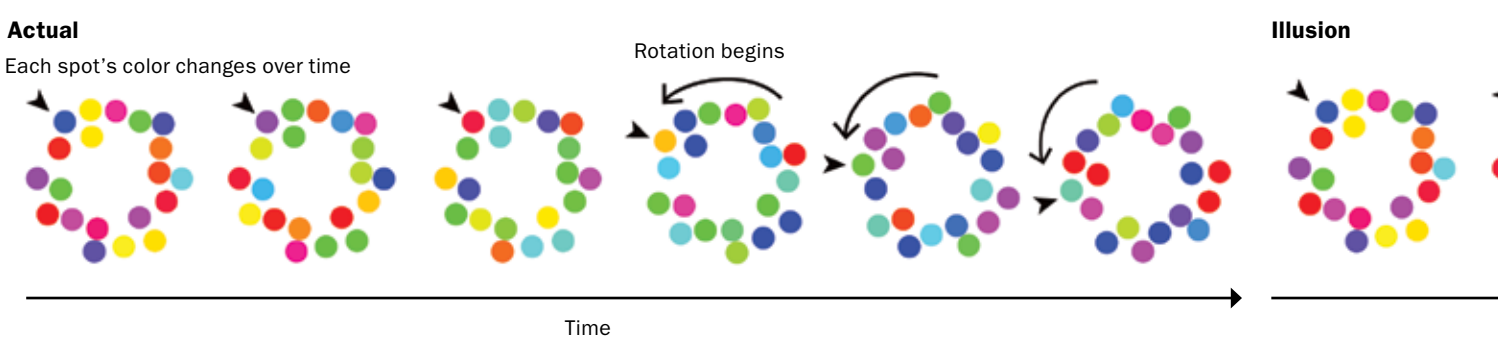
MIND-WARPING VISIONS

10 BRAIN TWISTERS COMPETE TO BE THE BEST ILLUSION OF 2011

BY STEPHEN L. MACKNIK AND SUSANA MARTINEZ-CONDE

Jordan Suchow came to three rapid-fire conclusions as he watched his Macintosh laptop plummet toward the floor. First, in approximately 300 milliseconds he was going to be in a heap of trouble—the machine had been given to him by his thesis adviser, George Alvarez of Harvard University. Second, hoping against all hope, he decided that Harvard could probably afford to buy him a new computer. Third, he realized that the most important observation of his life was unfolding right in front of him as his laptop accelerated toward the parquet: the onscreen doughnut that he had programmed to scintillate appeared to have stopped doing so.

COURTESY OF HÉCTOR RIEIRO *Barrow Neurological Institute*



Suchow's Ph.D. research project on cognition and attention had required him to program a visual display in which every element changed continuously, hence the scintillating doughnut. While working on the project at home, Suchow pulled his Mac from a coffee table to his lap. During the transfer, he noticed that the cycling of the doughnut's colors seemed to slow down. Startled, he dropped the machine altogether and was fascinated to see the color cycling cease completely as the doughnut fell.

His accidental discovery won the top prize at the 2011 Best Illusion of the Year Contest. A professional wrestling match of the minds, the contest barraged the audience's brains with perceptual pile drivers, mental Mongolian chops and cognitive clotheslines—moves designed to conjure up a reality that does not actually exist.

Inside your brain, you create a simulation of the world that may or may not match the real thing. Your "reality" is the result of your exclusive interaction with that simulation. When you experience an illusion, your perception differs from physical reality in substantial ways. You may see something that is not there, or fail to see something that is there, or see something differently from the way it actually is. Suchow's visual neurons failed to see the doughnut's scintillating colors, even though they were most definitely there.

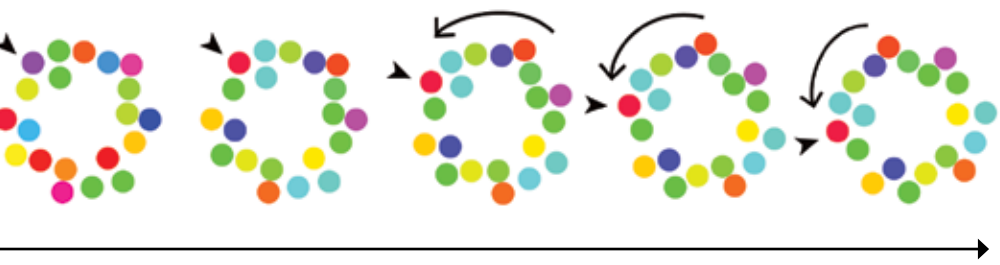
Yet illusions are not the failures of perception that they are often portrayed to be. Rather they can result from evolutionary adaptations. Sometimes illusions occur because of shortcuts that your brain takes to help you survive and thrive. They allow you to make lightning-fast assumptions that are technically wrong but helpful in practice. For example, you may underestimate or overestimate distances, depending on various contextual cues. In 2007 psychologists Russell E. Jackson of California State University, San Marcos, and Lawrence K. Cormack of the University of Texas at Austin reported that observers estimated the height of a cliff when looking down from the top to be 32 percent greater than when looking up from its base. Given that accidents are more likely to happen while climbing down rather than up, this miscalculation may make you descend cliffs with greater care, reducing your chances of falling.

Illusions also offer a window into how our neural circuits create our first-person experience of the world. Suchow's doughnut is just one of this year's top illusions that rely on a phenomenon called silencing, in which changes go unseen because the motion of something else captures all the viewer's attention. Silencing illusions are reminiscent of the magician's adage that "a big motion covers a smaller motion."

As with most of the top illusions of the past few years, most of the 2011 winners are "dynamic"—that is, they rely on moving images to work their magic. Such images are difficult to reproduce on the printed page; instead this article reveals the secrets behind the illusions. We en-

The first-, second- and third-place trophies (*right*) awarded to the contest winners (*above*) are sculptured illusions created by Italian artist Guido Moretti.

COURTESY OF JAN DREWES (*top*); COURTESY OF INNA TSIRLIN (*bottom*)



SILENCING COLOR: In this winning illusion, the color of every dot in the doughnut changes over time. When the doughnut rotates, the colors continue to change, but viewers do not notice these changes—perhaps because the motion stifles awareness of the shifting colors—even though they can accurately report the current color of the dots if asked.

WHEN YOU PAY ATTENTION TO A PART OF A VISUAL SCENE, THE SURROUNDING MOTION IS SUPPRESSED.

courage you to view the winning illusions, including two that cannot be shown here, in their animated form on the Web at http://illusionoftheyear.com/2011.

Illusions competing in the Best Illusion of the Year Contest must be novel: that is, previously unpublished or published within the past year. An international panel of experts selects the 10 illusions that are the most counterintuitive, spectacular, beautiful and significant to the understanding of the human mind and brain. The creators are invited to present their awe-inspiring brain twisters at a contest event where the audience votes to choose the winners of first, second and third prize: regarded as the "Oscars" of illusion.

Anyone can submit an illusion to the competition—scientists, artists, software designers, mathematicians or creative people from any field. Instructions are posted at http://illusionoftheyear.com/submission-instructions. The Best Illusion of the Year Contest's eighth annual gala, which is free and open to the public, will be held on May 14, 2012, at the Philharmonic Center for the Arts in Naples, Fla. Please join us and vote for the best illusion of the year! **M**

THE ROUNDS OF SILENCE

Like a rainbow-sprinkled doughnut, the eye-popping illusion created by Suchow and Alvarez claims your full attention. If you pick out a single dot from the crowd, you will see it change color over time … until the entire doughnut starts to rotate. Then the color cycling appears to stop. In fact, the color cycling never ceases. Somehow the rotation of the doughnut suppresses your perception of the color change. This "silencing" effect also works if you do not rotate the doughnut but instead view the colorful display as you hurtle down a roller coaster. Or fling your laptop into a gravity well while contemplating both the image on the screen and the benevolence of your boss.

The biological explanation for this illusion is unknown, but it might be connected to the neural circuits for attention that we discovered in collaboration with the laboratories of neuroscientists Jose-Manuel Alonso of the S.U.N.Y. College of Optometry and Harvey Swadlow of the University of Connecticut. Our results, published in 2008, showed that motion-sensitive circuits in the visual area of the brain known as V1 are intimately linked to our attentional spotlight, so that when you pay attention to a specific part of a visual scene, the surrounding motion is suppressed. In the case of Suchow and Alvarez's silencing illusion, motion may attract the observer more powerfully than color swaps, causing suppression of the latter.

http://illusionoftheyear.com/2011/silencing-awareness-of-change-by-background-motion

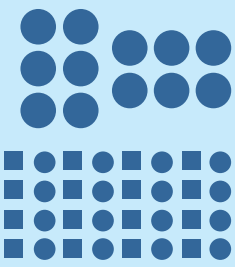
THE GERMAN GESTALT

Peter Thompson of the University of York in England, a leader in the field of visual perception and illusions, emceed the gala. He announced one contestant by asking the audience, "Where would we be without fun and laughter? Germany! Which is where this next illusion comes from." Psychologists Erica Dixon and Arthur Shapiro, both Americans from American University in Washington, D.C., and Kai Hamburger, an actual German from the University of Giessen, call their illusion grouping by contrast. It introduces a stunning new facet to the Gestalt laws originally formulated by German psychologists.

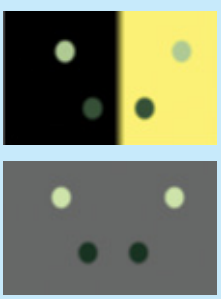
As Dixon explained in her onstage presentation, two of these laws are relevant to the illusion that her team created: the law of proximity, in which objects near one another tend to be grouped together, and the law of similarity, in which objects similar to one another are also clustered. Dixon and her colleagues discovered a new grouping principle that is even more powerful than the previous two laws combined. In their grouping by contrast illusion, the researchers showed that the brain tends to bundle objects with similar absolute contrasts, a propensity that was previously unknown.

Absolute contrast is the magnitude of an object's contrast with respect to its background, irrespective of whether the object is light on dark or dark on light. Surprisingly, the brain prefers to group objects by their absolute contrast rather than by their proximity or similarity, or both these traits combined. When you see four spots, two in the top row blinking together from dark to light and two in the bottom row blinking in opposite phase, with a background that is light on the right and dark on the left, the brain groups the spots along the diagonal—even though the spots that are both closest and most similar are across rows. The brain prefers the diagonal pairing because those dots share the same level of contrast—the difference in the brightness between every dot and its background. This new and critically important observation will no doubt guide research into how the brain computes object categorization. The work won second prize at the 2011 contest.

http://illusionoftheyear.com/2011/grouping-by-contrast



GESTALT LAWS: The law of proximity states that objects near one another, such as the circles at the upper left, appear to form a group—in this case, in columns and rows. The law of similarity states that objects that are similar, such as the squares shown at the lower left, seem to belong together.



GROUPING BY CONTRAST: The viewer's brain insists on pairing blinking dots diagonally when they share the same level of contrast with their background (*upper right*). With this contrast removed, the brain pairs the dots by proximity and similarity (*lower right*).

LEFT TO RIGHT: FROM "MOTION SILENCES AWARENESS OF VISUAL CHANGE," BY JORDAN W. SUCHOW AND GEORGE A. ALVAREZ, IN *CURRENT BIOLOGY*, VOL. 21, NO. 2; JANUARY 25, 2011. REPRINTED WITH PERMISSION FROM ELSEVIER; SCIENTIFIC AMERICAN MIND; COURTESY OF ERICA DIXON AND ARTHUR SHAPIRO *American University* AND KAI HAMBURGER *University of Giessen*

THE LOCH NESS AFTEREFFECT

Mark Wexler of the University of Paris V in France took third-prize honors with his Loch Ness aftereffect. He named it after a classic illusion that was known to the ancient Greeks and rediscovered in 1834 by Robert Addams at the Falls of Foyers, which are the waterfalls that feed Loch Ness in Scotland. Addams noticed that after he stared at the waterfalls for a while, stationary surfaces, such as the rocks and vegetation beside the falling water, appeared to drift upward.

In Wexler's illusion, the viewer stares at a red dot surrounded by a rotating ring of dashes. Suddenly the ring jumps in the opposite direction with a rapid rotation, before continuing to turn slowly in the original direction again. Wait—the ring is not really jerking backward at all—that's all you, baby! In reality, the ring's elements are simply reassorted at random. Unlike the illusory motion described by Addams, which is slower than the real movement that induces it, Wexler's faux motion is 100 times faster than the inducing movement.

Wexler's illusion is called an aftereffect because you perceive it once the physical motion stops—for instance, when you see spots after a camera flash—but here it works specifically for motion-sensitive neurons. Wexler says the illusion is related to how the brain matches the starting points of moving objects to the next points along the motion trajectory. Presented with a burst of random visual noise, the brain finds no consistent correspondences and is forced to take a guess at the best possible matches, which happen to be far away because of the randomization, resulting in the observer's perception of fast motion. Only future research will determine the specific neural underpinnings of this effect.

http://illusionoftheyear.com/2011/the-loch-ness-aftereffect

JUMPING RING: The dashes that make up a rotating ring are periodically rearranged in random fashion. The viewer's brain, unable to match the new arrangement with the expected trajectory, perceives this as a rapid backward rotation.

MASK OF LOVE

Courtney Smith presented the mask of love illusion, created in collaboration with Gianni Sarcone and Marie-Jo Waeber of the Archimedes Laboratory Project in Genoa, Italy. A young girl in a Venetian mask pines for love. Or perhaps she is beyond the yearning period and has moved on to kissing. This type of illusion is called bistable because, as in the classic face-vase illusion, you may see either a girl or a couple, but not both at once. The visual system tends to see what it expects to see—only one mask is present, so you are much more likely to see a single face on first glance.

The illusion was discovered in an old photograph of two lovers sent to the Archimedes Laboratory. Sarcone, the leader of the group, saw the image pinned to the wall and, being nearsighted, thought it was a single face. After donning his eyeglasses, he realized what he was looking at. The team later paired the picture of the lovers with the beautiful Venetian mask. Luck does favor the prepared mind … and the nearsighted.

http://illusionoftheyear.com/2011/mask-of-love

SEEING DOUBLE: Most people initially see one face here because of the surrounding mask. But look again, and you'll see two.

COURTESY OF MARK WEXLER *University of Paris V (top)*; COURTESY OF ARCHIMEDES LAB PROJECT *(bottom)*

(The Authors)

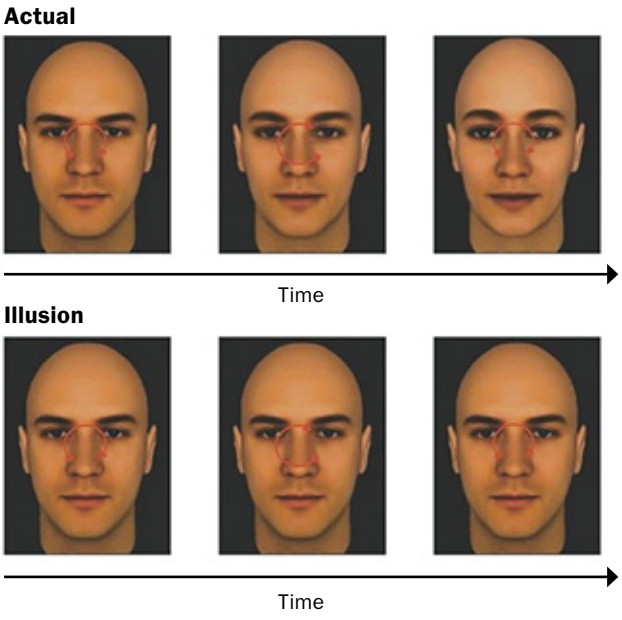
STEPHEN L. MACKNIK and SUSANA MARTINEZ-CONDE are laboratory directors at the Barrow Neurological Institute in Phoenix. They are authors of the recently published book *Sleights of Mind: What the Neuroscience of Magic Reveals about Our Everyday Deceptions,* with Sandra Blakeslee, now out in paperback (http://sleightsofmind.com). Their forthcoming book, *Champions of Illusion,* will be published by Scientific American/Farrar, Straus and Giroux.

HE OR SHE?

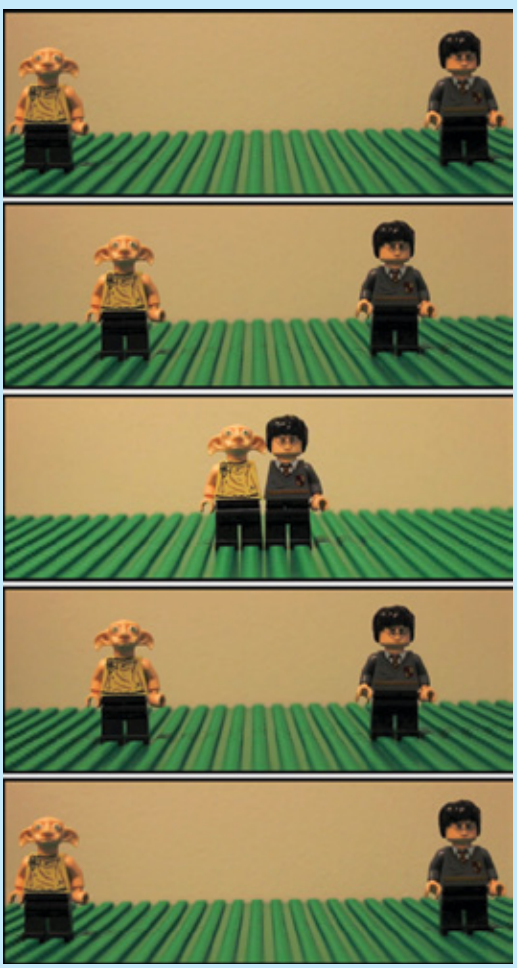
Rob van Lier and Arno Koning of the Donders Institute in the Netherlands asked the audience to keep their eyes on a circling red dot superimposed on a face. When the dot disappeared a short while later, the face morphed from that of an androgynous male to one that looks more female and then back to male. When the red dot reappeared for the audience to follow, the faces stopped morphing. In reality, the faces had morphed continuously the entire time and appeared unchanging only when viewers focused on the moving red dot. Van Lier demonstrated that the illusion also worked when he altered the emotions and the age of the faces and even when he used famous examples, such as Barack Obama's face changing between happy and sad expressions.

Just as with Suchow and Alvarez's silencing effect, the neural underpinnings of this illusion are unknown but could have their roots in how attention works in the brain. In this particular case, closely watching the moving dot may suppress neural activity in the fusiform gyrus, the part of the brain that processes faces.

http://illusionoftheyear.com/2011/the-more-or-less-morphing-face-illusion



TWO-FACED: The face in this illusion morphs over time, shifting from predominantly male characteristics to more feminine ones and back again. Viewers who focus on a circling red dot fail to see the face changing.



IN A BIND

Shapiro, who had a hand in the grouping by contrast illusion, developed a second illusion, this one with Gideon Caplovitz of the University of Reno. First, Shapiro showed two vertical bars, one red and one green, sweeping left and right across a screen. When the bars met in the middle of the screen, they changed colors and rebounded off each other, streaked back to the edge of the screen and bounced back to the middle. Shapiro asked the audience to look at a spot above the screen while paying attention to the bouncing bars. People "oooooohed" as they saw the bars once again collide, but instead of ricocheting the bars now seemed to pass through each other and retain their original color. Shapiro went on to show that the pass-through effect also works with textured, rather than colored, bars. He even demonstrated the illusion using Lego figurines of Harry Potter and his elf buddy Dobby, raided from his child's closet.

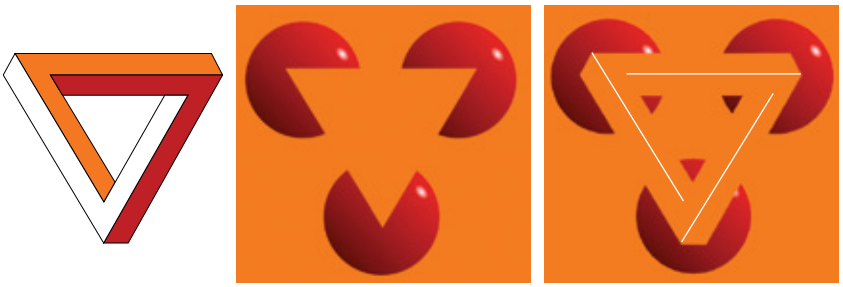
This little gem of an illusion helps us pick at the corners of what neuroscientists call the binding problem. The cortex (Latin for "bark," or "outer layer") of the brain is organized into areas that process particular types of information. Motor and cognitive processes take place in the frontal lobes of the brain, vision is in the back, and so on—with specific visual areas dealing with motion, color, texture and faces. If you look in the mirror and move your head from side to side cobra-style, somehow your brain must bind together the outputs of all the different areas involved in watching your moving face. Shapiro and Caplovitz's dramatic illusion shows that features bound to one object can rebind to a different moving object. The fact that the illusion varies in step with changes in the objects' location on the retina gives scientists a valuable clue for studying the neural basis of this effect.

http://illusionoftheyear.com/2011/the-exchange-of-features-textures-and-faces

JUST PASSING THROUGH: Harry Potter and Dobby bounce off each other as they meet midscreen. To a viewer focused on a spot above the screen, however, the toys appear to pass through each other—an example of how the brain can bind the features of one moving object to another.

COURTESY OF ROB VAN LIER AND ARNO KONING *Donders Institute (top)*;
COURTESY OF ARTHUR SHAPIRO *American University* AND GIDEON CAPLOVITZ *University of Reno (bottom)*

THE BRAIN MIGHT FILL IN NOT ONLY VISUAL INFORMATION BUT ALSO TACTILE SENSATIONS.



ANGLO-ITALIAN: Combining the Penrose triangle (*left*) with the Kanizsa triangle (*center*) yields an illusion that is simultaneously filled in and impossible (*right*).

TWO TRIANGLES

Christopher Tyler of the Smith-Kettlewell Eye Research Institute in San Francisco invented the magic eye illusions that were all the rage in the 1990s. In true academic tradition, of course, he never made a cent off them. At the 2011 contest he began his presentation by exhibiting the Penrose triangle, the quintessential impossible object, drawn in 1958 in its most familiar form by Roger Penrose of the University of Oxford. Tyler also displayed another famous triangle, first described by Italian psychologist Gaetano Kanizsa in 1955, which shows that the brain can create entire objects by filling in missing information. Tyler wondered whether he could integrate the two perceptual traditions. When he laid the outline and inner crossbars of the Penrose triangle over the three red balls making up the Kanizsa triangle, he discovered that the brain will fill in even impossible figures.

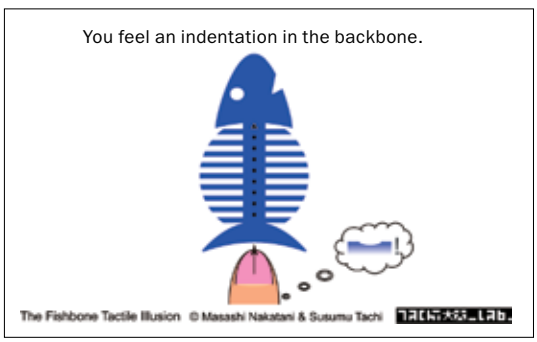
Tyler's illusion reveals that our brain constructs the feeling of a global percept—an overall picture of a particular item—by sewing together multiple local percepts. As long as the local relations among surfaces and objects follow the rules of nature, our brain does not seem to mind that the global percept is impossible or that its local features contain only the sparsest information.

http://illusionoftheyear.com/2011/impossible-illusory-triangle

THE MAGIC TOUCH

The first tactile illusion ever presented at the contest gives you a very fishy feeling. Masashi Nakatani of Keio University in Japan, costumed in spearfishing attire, passed out business cards embossed with ink in the shape of a stylized fish. With the flourish of a magician, Nakatani approached emcee Thompson onstage and told him, "Rub your finger up and down the spine. Up and down the spine. You feel a groove there? But … there … is … none!" Thompson rubbed the fish's spine as instructed. "How do you feel?" Nakatani asked. "I feel dirty for feeling up this fish," Thompson deadpanned. "But I do feel a groove here."

Nakatani was intrigued by the possibility that the brain might fill in not only visual information but also tactile sensations. He thought he could create a texture that was not a circle but would feel like one. The fishbone pattern (without a head or tail) was one of many botched attempts. Disappointed, Nakatani took the sample to a senior colleague, Susumu Tachi, to describe his failure. Tachi agreed that the texture did not feel like a circle, but he noticed a central groove where there was none. He encouraged Nakatani to change his dissertation project to study the fishbone illusion full-time. By testing a variety of configurations and textures, Nakatani and his colleagues were able to determine that the illusion arises from how tactile receptors in your skin compare smooth and rough textures: your brain interprets the smooth spine to be lower than the rough ribs of the fish—and you're hooked.



FISHY FEELING: Rubbing your finger over a ribbed pattern gives the illusion of a grooved spine, thanks to the difference between the raised and flat textures.

http://illusionoftheyear.com/2011/fishbone-tactile-illusion

(Further Reading)

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SCIENTIFIC AMERICAN MIND; COURTESY OF CHRISTOPHER W. TYLER *Smith-Kettlewell Eye Research Institute (top)*; COURTESY OF MASASHI NAKATANI AND SUSUMU TACHI *Keio University (bottom)*

CHIP SIMONS (*outline*); ERIC REICHBAUM *Getty Images (smoke)*

BELIEF IN THE PARANORMAL ARISES FROM THE SAME BRAIN MECHANISMS THAT SHAPE MOST HUMAN THOUGHT

BY RICHARD WISEMAN

You may have never personally caught sight of Jesus Christ's face in a potato chip, but you have likely succumbed to an equally improbable belief at some point in your life. Many people claim that ghosts exist or that their dreams can predict the future. Some individuals even think they have seen the face of the Virgin Mary in a grilled cheese sandwich and Mother Teresa in a cinnamon bun.

WIRED FOR WEIRD

Although such beliefs may sound farfetched, they are surprisingly common. An opinion poll conducted in 2005 showed that three out of four Americans believe in the existence of paranormal phenomena. Other work has revealed that about one in three of us claim to have experienced the supernatural. The sheer ubiquity of these experiences has led many psychologists to wonder whether common mechanisms might underlie some of these widespread convictions.

The list of strange effects that members of our species believe in ranges far beyond the limits of scientific evidence, including telepathy, clairvoyance, foreknowledge of the future, the control of matter with one's mind and the ability to commune with the dead. Psychologists are now beginning to tease out why so many of us believe in phenomena that defy logical explanation, revealing a surprising truth. Belief in the paranormal is not the provenance of a select group of individuals who are fundamentally different from the rest of us. We are all wired for weird.

Since the 1930s researchers have sought solid proof of psychic abilities by testing whether individuals could discern the order of a deck of cards, to no avail.

The Dream of Prophecy

The scientific study of allegedly paranormal phenomena began in earnest with pioneering work in the 1930s by parapsychologist Joseph Banks Rhine of Duke University. Originally trained as a botanist, Rhine attended a lecture on spiritualism given by author Arthur Conan Doyle, who alerted him to the possible existence of extrasensory perception. Rhine and his colleagues spent the next 40 years investigating whether people could deploy psychic skills to figure out the order of a shuffled deck of cards.

Rhine's early results looked promising, but his findings proved difficult to replicate, and researchers eventually moved away from card guessing and developed other types of experiments to probe the paranormal. This pattern has repeated itself for the past 80 years, with scientists reporting that a new experimental procedure had finally produced solid evidence for extrasensory perception, only to discover that their initial success could not be reproduced [*see box on opposite page*]. In the 1980s several researchers working in different universities across the world became disillusioned with the emergence of one false dawn after another, and as one parapsychology laboratory after another closed down, they turned their attention to a far more robust phenomenon—why so many people believe in the paranormal.

To explain some of these supernatural effects, my colleagues and I have drawn heavily from some of the biggest findings in psychology in recent decades, especially regarding the irrational behaviors that we all display in most aspects of our life. For example, consider dream precognition, which is the sense that a dream foreshadows reality. It is one of the most commonly reported forms of paranormal belief. Research into the science of sleep has revealed that the vast majority of people have about four dreams a night, with each one lasting around 15 minutes. Once in a while, some people experience an uncanny resemblance between one of their dreams and subsequent events, and they infer that they possess the gift of prophesy.

In 1993 psychologist Scott F. Madey, now at Shippensburg University, reported an experiment that he and his colleagues had designed to find out how common the tendency to link dreams with reality is. The researchers asked a group of students to read a diary supposedly written by someone who thought she had precognitive dreams. The diary contained a description of all the dreams, along with an account of events from her life, that either suggested the dream had been accurate or inaccurate. When asked to remember as many of the dreams as possible, subjects recalled about 60 percent of the ones that coincided with a real-life event versus just 40 percent of the others. The result suggests that we generally remember the dreams that come true better than those that do not.

THE SAME MECHANISMS THAT ENABLE YOU TO SEE PATTERNS AND DRAW CONCLUSIONS FROM LIMITED DATA CAN ALSO TURN UP FALSE POSITIVE RESULTS—OR EVEN GO INTO OVERDRIVE.

The psychology literature is rich with examples of this effect outside the realm of the paranormal. In the mid-1990s, for example, researchers Donald Redelmeier of the University of Toronto and Amos Tversky of Stanford University investigated the purported link between arthritic pain and the weather. For hundreds of years sufferers have convinced themselves that their arthritis flares up with certain changes in temperature, barometric pressure and humidity. To find out if this was really the case, Redelmeier and Tversky asked a group afflicted with rheumatoid arthritis to rate their pain levels twice a month for more than a year. The research team then obtained detailed information about the local temperature, barometric pressure and humidity over the same period. All the patients believed the weather worsened their pain. The data, however, showed no such relation. The subjects, it seemed, had focused on the times

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FAST FACTS

Otherworldly Observations

1» Most of us report that we believe in supernatural powers such as clairvoyance and telepathy and in the existence of ghosts.

2» The widespread reports of paranormal experiences very likely derive from many of the same mechanisms that help us make decisions in daily life.

3» Research suggests that a highly active right-brain hemisphere may cause someone to be particularly susceptible to improbable beliefs.

That we see faces in light and dark patches reflects the brain's finely honed pattern-recognition skills.

when high levels of pain were associated with especially odd weather patterns, forgotten about the times when this was not the case, and erroneously concluded that the two were related.

The fact that we sometimes see patterns where none exist is largely a side effect of our normal reasoning. In our daily lives we repeatedly encounter pairs of events that are genuinely related: You press the accelerator pedal, and your car speeds up. You see gray clouds in the sky, and seconds later it starts to rain. You eat food that tastes odd, and soon you start to feel ill. Indeed, not drawing connections between events could threaten your existence. The same mechanisms that enable us to draw conclusions quickly from limited data can also turn up false positive results—or even go into overdrive.

Ghost in the Machine

A similar line of reasoning can explain our reactions to things that go bump in the night. In 2004 psychologist Justin Barrett of the University of Oxford proposed one of the most popular theories about why people believe in ghosts. He thinks some of our paranormal proclivities stem from a neural mechanism he termed the agency-detection device.

Understanding what motivates people, Barrett argues, is essential to our everyday interactions with one another. Just as recognizing patterns in sparse information can sometimes lead us astray, the parts of the brain responsible for detecting the reasons behind actions can cause almost all of us to see humanlike behavior in even the most meaningless stimuli.

For example, consider the now classic experiment from the 1940s by psychologists Fritz Heider and Mary-Ann Simmel. Heider and Simmel created a short cartoon animation in which a large triangle, a small triangle and a circle moved in and out of a box. When people watch this meaningless cartoon, they instantly create elaborate stories to explain what is going on. They might say, for instance, that the circle was in love with the little

(The Author)

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The **Debunker's** Dilemma

Over the years dozens of parapsychologists have claimed to have produced evidence of the existence of extrasensory perception. For science to move forward, however, other experimenters must be able to replicate those results. Herein lies a problem: in the world of science publishing, original studies are often published, but failed replications are not, leaving readers with just one side of the story.

In 2010 parapsychologist Daryl J. Bem published in a high-profile psychology journal a series of experiments that seemed to support the existence of precognition. The paper describes several studies involving more than 1,000 participants. In one experiment, for example, participants were shown a list of words and then asked to recall as many words as possible. A few moments later they were shown a random selection of words from the original list. Spookily, the results revealed that the participants were better at recalling words that they later saw a second time. Their memory seemed to be affected by the words they would see in the future.

The following year I teamed up with psychologists Stuart Ritchie of the University of Edinburgh and Chris French of Goldsmiths, University of London, to attempt to reproduce Bem's controversial findings. We each ran our own independent study replicating the precognitive memory experiment. (Bem himself thought that it would be the easiest one in his series to reproduce.) Bem kindly provided us with the software he had used to run his study, and we did our best to duplicate his methods and setup. All our three studies obtained null results, suggesting that parapsychologists have yet to find the Holy Grail of a replicable effect.

When we submitted our results for publication, however, several journals refused to review our paper on the grounds that they did not publish attempted replications. We believe that such policies represent a real problem not just for parapsychology but for mainstream psychology, too. To verify that an effect is genuine, it is vital that other scientists attempt to replicate findings in their own laboratories and can publish the results of their work. By refusing to publish attempted replications, journals make it virtually impossible to assess a finding and so can leave both psychologists and the public with the mistaken impression that an effect is much more robust than is actually the case. *—R.W.*

CHIP SIMONS *Corbis (toast)*; GETTY IMAGES *(scientist)*

OUR SUPERB AGENCY-DETECTION SKILLS MIGHT EXPLAIN WHY MANY OF US BELIEVE IN GOD, GHOSTS AND GOBLINS—SOME **PEOPLE MAY SEE CAUSAL LINKS MORE READILY THAN OTHERS.**

triangle and that the big triangle was attempting to steal away the circle. But the little triangle fought back, and eventually it and the circle lived happily ever after. The experiment illustrated beautifully that almost everyone has the capacity to perceive intentions and purpose where none exists.

Our superb agency-detection skills might explain why so many of us believe in God, ghosts and goblins—perhaps some of us see causal connections more readily than others. If Barrett is right, ghosts are the price we pay for having remarkable brains that can effortlessly figure out why other people behave the way they do.

Agency detection does not explain everything, of course—we also excel at discerning faces in arbitrary objects. In 2009 my colleagues and I teamed up with the Edinburgh International Science Festival to carry out a large-scale public experiment on the science of ghosts. Part of the project involved asking anyone who thought they had photographed a spirit to submit their image for examination. We received more than 1,000 pictures from around the world, none of which provided compelling evidence of the existence of spirits. Often we could not see the alleged apparition at all, even though the photographers insisted that the ghostly face was easy to spot hiding in the darkness, say, or in a plume of smoke. For such phenomena, spooky photographs are the tamest examples, with some people claiming to see supernatural faces in the strangest places, including observing the likenesses of famous religious figures in all sorts of bread products. These individuals are most likely experiencing yet another case of normal brain processes going into overdrive.

Faces are vital to our survival, and several brain-scanning studies have revealed that significant chunks of the brain are dedicated to spotting and identifying visages. As with our strong pattern-recognition skills, the ability to identify faces has been refined through millions of years of evolution. Neglecting to notice an unfriendly mug could put you in serious danger. This phenomenon, called pareidolia, explains why the Internet is littered with photographs of plugs, cars and houses that appear to resemble human faces. Yet in the same way that the agency-detection device can spiral out of control and cause people to believe in ghosts and goblins, some people's face-recognition systems can become hyperactive and lead them to observe eyes and mouths everywhere.

Grand Theory of Paranormality

Although we are still in the early stages of learning which features of the brain cause us to form unscientific ideas, one in-

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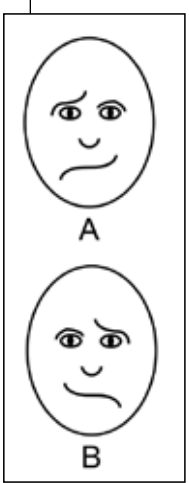
Humans are innately drawn to look at faces. Most of us will also see eyes and mouths in chipped paint and other arbitrary places. This cognitive tendency, among others, helps to explain why our brain can string together numerous otherworldly explanations for everyday events.

teresting finding suggests a possible unifying theory for belief in ghosts, precognition, telepathy, and the like.

Numerous psychologists and neuroscientists have shown that despite our brain having two hemispheres, those two halves are actually surprisingly similar and capable of carrying out the same kinds of tasks. Still, each hemisphere does tend to specialize in certain ways of thinking. The left hemisphere is better at language, mathematics and logical thinking, among other things, whereas the right half excels at face recognition, certain aspects of creativity, visual imagery and music. Some psychologists think that people differ in the extent to which they rely on the two hemispheres, thus making them more experiential or rational in their preferred way of thinking about themselves and the world.

In a series of experiments that began in the late 1990s, neuropsychologist Peter Brugger of University Hospital Zurich noticed that many of the effects that cause people to think they have experienced paranormal phenomena are associated with the right hemisphere. For example, these individuals tend to value intuitive thinking over rationality and are especially good at perceiving faces where none exist. Brugger speculated that those who regularly undergo seemingly supernatural happenings might have a more dominating right hemisphere. For the past 10 years Brugger and his colleagues have been conducting a series of fascinating experiments to examine this somewhat contentious notion. Take a look at the figure at the left.



Which of the two images look happier? In drawing A the person is smiling on the right side of the face, and in drawing B the individual is smiling on the left side. We perceive visual information using the hemisphere opposite the eye that took it in, such that data from the left side of an image is fed to the right hemisphere, and vice versa for the right side of the drawing. Some researchers have speculated that people with more dominant right hemispheres will be more influenced by their perception of the left side of the face and so be more likely to indicate that face B looks happier than face A. Other tests of this imbalance have involved trying to walk blindfolded down the middle of a corridor, a task during which right-dominant individuals tend to veer left. Psychologists have also asked people to mark the center of a line drawn on a piece of paper, which right-dominant subjects tend to place left of center, and to quickly guess what number lies halfway between 15 and 3, which typically generates lower estimates from right-dominant types.

Brugger has administered these types of tests to hundreds of subjects and also asked them to indicate the degree to which they believe in paranormal phenomena. Initial results have revealed that those individuals who have experienced the impossible do indeed tend to produce responses associated with being right-dominant. According to the theory, such people would be especially likely to make associations between unconnected events, see faces in ambiguous shapes and sense patterns where there are none. This inclination, in turn, makes them more likely to experience seemingly impossible phenomena such as seeing ghostly faces in photographs and having dreams that appear to come true. If future research continues to confirm his idea, Brugger may well be laying the groundwork for a unifying theory of paranormal belief.

Think of it this way. Almost all our physical and psychological traits vary along a continuum—certain people are tall, and others are short; some individuals are outgoing, whereas others are shy. Yet the great majority of us land somewhere in the middle, and the same goes for belief in the supernatural. M

How to See a Ghost

Stand about half a meter in front of a large mirror. Next, place a candle or other dim light directly behind yourself and turn off the lights. After gazing at your reflection for about a minute, you will start to experience a strange illusion. According to work conducted by Italian psychologist Giovanni B. Caputo of the University of Urbino, about 70 percent of people see their face become horribly distorted, and many individuals eventually see it contort into the face of another person. Although researchers are not sure what produces the weird effect, the lighting condition seems to prevent your brain from "binding" together the different features of your face into a single image. —*R.W.*

(Further Reading)

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- **The Belief Instinct: The Psychology of Souls, Destiny, and the Meaning of Life.** Jesse Bering. W. W. Norton, 2011.
- **The Believing Brain: From Ghosts and Gods to Politics and Conspiracies—How We Construct Beliefs and Reinforce Them as Truths.** Michael Shermer. Times Books, 2011.
- **Paranormality: Why We See What Isn't There.** Richard Wiseman. Kindle edition. Spin Solutions, 2011.

COURTESY OF RICHARD WISEMAN *University of Hertfordshire (faces)*; GETTY IMAGES (*mirror*)

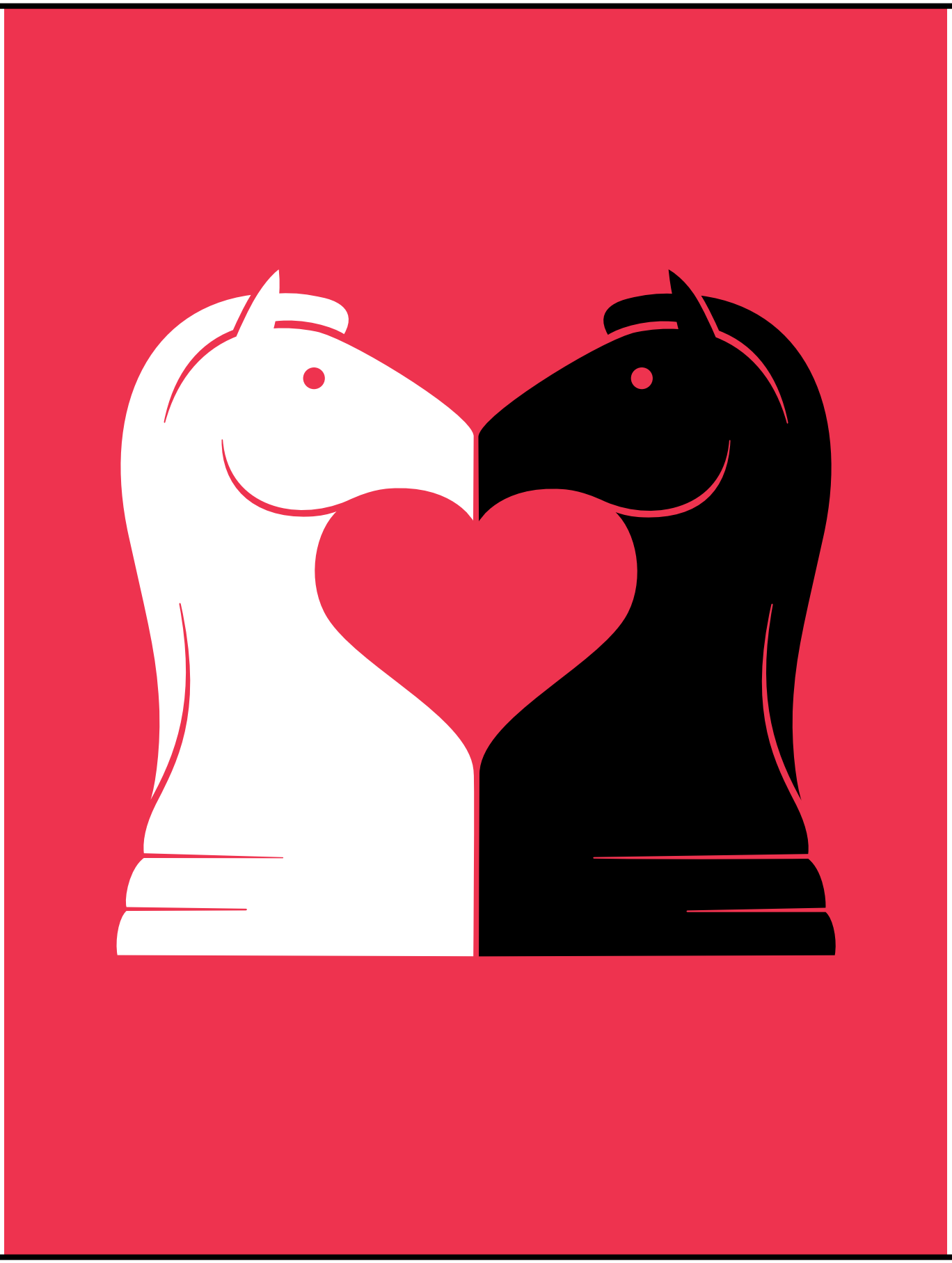
THE PARTNERSHIP PARADOX

Why the person you love most is also the one most likely to drive you mad

There are people who meet, fall in love, stay married for their entire lives, and never have an unkind word for their spouses. Then there are the other seven billion people on the planet.

Men and women frequently describe their partners as both "the love of my life" and "one of the most annoying people I know." It is a baffling paradox. Consider the following scenario, which has played out a million times at dinner parties around the world. Think of it as a theme with endless variations.

By Joe Palca and Flora Lichtman Illustration by Noma Bar



Four couples are sitting around a table. Everybody is on a second glass of wine. One of the men at the table starts to tell a joke.

"So, three strings go into a bar. The first string says to the bartender, 'I'd like a Tom Collins.'"

The man's wife interrupts. "Please, not that joke again."

He turns to her. "But they haven't heard it."

She avoids his look. "I have. A thousand times."

A physically attractive person can become a high-maintenance spouse.

"But it's funny."

"So you think."

Now the incident has reached a turning point. The guy can finish telling the joke, which will tick off his wife. Or he can stop telling the joke, in which case he'll be irritated.* When they get home, it is easy to imagine the conversation.

"Why do you always interrupt me when I try to tell a joke? When we started dating, you liked my jokes."

"That's all you ever do at dinner parties. Tell jokes. We were talking about politics, and you pipe up with your dumb joke about strings."

"Can't you ever let me finish a thought in public? Can't you let other people decide what they do or don't want to hear?"

And so on.

A reasonably well-adjusted couple will weather this contretemps. For a troubled marriage, it could take them one step closer to the end. Diane Felmlee, a sociologist at the University of California, Davis, has thought a lot about the circumstances that bring couples to this predicament. The answer first occurred to her in the 1980s, when she was starting her academic career at Indiana University Bloomington. She even remembers the day. She was having lunch with some of her women friends when the conversation turned to relationships. "One woman was saying her husband was never there on the weekends," Felmlee recalls. "He was always working so hard, and she wished he was around more. So I asked her what drew her to him in the first place."

Felmlee says her friend replied that she and her husband had been high school sweethearts, and what had first impressed her about him was that he was an incredibly hard worker. "It was clear he was going to be one of the more successful people in the class," Felmlee remembers her friend saying. "Another woman said that her fiancé never talked with her about his feelings. So I asked her, 'What drew you to him?' and she said, 'Well, he had this cool about him, a kind of cool demeanor.' And I'm thinking, 'Cool, reserved men don't emote. They're not going to talk about their feelings.'" In every case, it seemed that the very quality that was initially attractive became an irksome characteristic later in the relationship.

Fatal Attraction

Felmlee decided to investigate. At the time, she was teaching a big lecture class. College sophomores are a common proving ground for new psychological theories, so it only made sense for her to engage her class. "I just had them pull out a piece of paper and asked them to think of their boyfriend or girlfriend and then write down what first attracted them to that person."

When you are the teacher, and you ask your class a question, you run a high risk of getting the answers your students think you want to hear. So she then posed a few unrelated questions to disguise what she was getting at. "And then I asked them what they least liked about that person. And if their relationship had ended, I asked why it ended."

The answers confirmed her initial suspicions. It was fairly common for the students to be turned off by the very thing that first attracted them to the person they were—or had been—dating. In the past few decades Felmlee has been conducting studies with couples to explore this problem of what she calls "fatal attractions." "We asked one guy what he liked about a former girlfriend, and he listed every part of

*The bartender says, "We don't serve strings here. Get out." The second string goes up to the bartender and says, "A Bloody Mary, please." The bartender says, "Didn't you hear what I told your friend? We don't serve strings here. Get out." Seeing this, the third string goes into the bathroom, unravels his ends and ties himself in a bow. Then he goes out to the bar and says, "I'd like a martini, please, straight up, with a twist." The bartender looks at him suspiciously. "Are you a string?" he asks. "No, I'm a frayed knot."

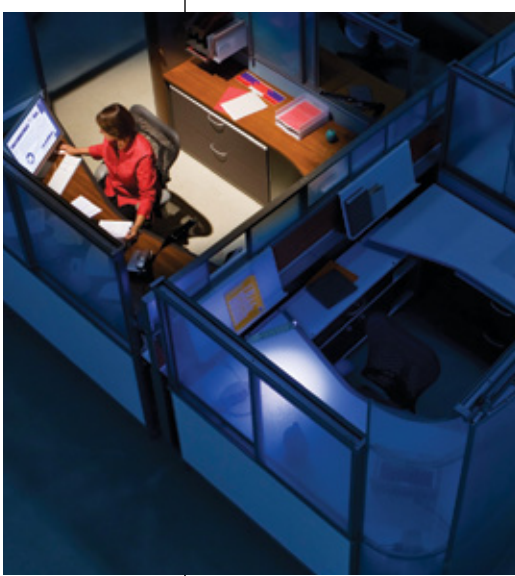
ANDREAS KUEHN *Getty Images*

this woman's body, including the most intimate parts. And when he answered the question 'Why did you split up?' he said that the relationship was based only on lust. There wasn't enough love. I thought, 'Well, he got what he wanted initially.'"

The list goes on. Felmlee says that someone who is seen as humorous at the start of a relationship can later be considered "flaky" or "immature." One woman reported that she was attracted by her boyfriend's sense of humor, but then she complained that he "doesn't always take other people's feelings seriously (jokes around too much)."

Caring is another positive quality with a downside. Felmlee reports that one woman was attracted to a man who was "very attentive" and persistent, but she disliked that he "tries to be controlling." Another woman described a former partner as "caring," "sensitive" and someone who listened to her. Yet she did not like the fact that he also got jealous very easily, and "he hated it when [she] wanted to spend time with other friends."

The highly successful love interest can later be seen as a workaholic.



For nearly every positive quality that you can think of, the flip side can later become annoying:

- People who are nice and agreeable can be seen as passive over time.
- Someone who is strong-willed can, with repeated exposure, appear stubborn and unreasonable.
- The outgoing, garrulous life of the party can also be the nonstop performer who will not shut up.
- The solicitous, caring suitor becomes the clingy, needy partner.
- An exciting risk taker later comes across as an irresponsible parent.
- A physically attractive person can become a high-maintenance spouse.
- Laid-back can also seem lazy.
- The highly successful love interest can later be seen as a workaholic.

In a way, fatal attraction resembles the inverse of a concept called hedonic reversal, which is when something that is intrinsically unpleasant—like eating hot chili peppers—becomes enjoyable with repeated exposure. We start off finding a quality of our mates attractive, and over time it becomes annoying. Felmlee has tested people all over the world, and the same pattern seems to hold.

The other thing she consistently finds is that the more strongly someone exhibits a particular trait, the more likely that trait is to become aggravating. Again, the dose matters. So, for example, a spouse will sooner become annoyed with a partner who is exceptionally funny and endlessly telling jokes than with one who makes a witty remark on occasion.

What's going on here? Why do strengths become weaknesses and endearing qualities irritants? "I call it disillusionment," Felmlee says. She believes the answer may be related to something called social exchange theory. "Extreme traits have rewards," she says, "but they also have costs associated with them, especially when you are in a relationship."

Take independence. "Independence can be valued in a partner, one who can stand on his own two feet," Felmlee says. "But if you're too independent, that means you don't need your wife. And that can have costs in a relationship."

Felmlee has thought a lot about how couples might get around some of these points. Self-awareness helps. She recalls one man who complained that his wife was stubborn. "On the other hand, what he really liked about her and loved from the beginning was her strength of character. And he said he was entirely committed to her and planned to be with her for

FAST FACTS

Am I Annoying Yet?

1» **The trait that initially attracts you to a person often later becomes your partner's most irksome feature.**

2» **Repeated exposure, disillusionment and the inescapability of a long-term partnership tend to make a spouse's traits more grating than the quirks of others.**

3» **Learning to reclassify annoying behaviors, increasing awareness of one's own flaws and sharing new experiences can help turn those peccadilloes back into perks.**

GETTY IMAGES

the rest of his life." This man, at least, seemed to be aware that positive qualities have an inherent downside. "And he seemed aware of his own limitations. He said, 'I'm stubborn, too, and she has to put up with that.'"

"It's not like you get this perfect person, and there are no downsides to his or her qualities," Felmlee says. "It just doesn't happen."

Social Allergens

Even if your partner only occasionally leaves a clump of hair in the drain or talks while he is eating, spending a lifetime with someone creates ample opportunities for repeated exposure. "The same thing keeps happening over and over and over again in a marriage," says Elaine Hatfield, a psychologist at the University of Hawaii at Manoa, "because we all have our goofy little quirks." Hatfield says that these annoyances get amplified according to the principles of something called equity theory.

The solicitous, caring suitor becomes the clingy, needy partner.

The idea is that social norms encourage groups and individuals to behave fairly with one another and that people are most comfortable when they feel they are being treated equitably. Equity theory says that if you feel your relationship is becoming lopsided, you will try to change that by restoring psychological or actual equity or by leaving the relationship. If the equity balance tilts toward you, and you are getting a good deal in a relationship, then you might be willing to ignore your partner's annoying habits and do less dishing out of things that get his goat.

"But if you think, 'That guy, he takes advantage of me at every turn, I'm stuck here with the eight children, I cannot leave, and he's out having a great time,' it would just grate on you more," Hatfield says.

(The Authors)

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Michael Cunningham, a University of Louisville psychologist, has come up with four basic categories for the small things that do not elicit much of a reaction at first but can lead to emotional explosions with repeated exposure—what he calls social allergens. Uncouth habits are behaviors that are not necessarily intended to be annoying but do the trick anyway—noisy flatulence and nose picking are two examples. Inconsiderate acts affect a specific individual, but they are not done with the express intention of bothering that person. For instance, your partner says she'll pick up the dry cleaning, and she forgets, time after time. Intrusive behaviors, on the other hand, are intentional. "This is a person who always insists on inflicting his opinion on you, whether you are interested or not," Cunningham says. Norm violations, he says, "are not directed at you personally but violate some standard that you have. For example, you know somebody who is not paying his income tax. It's not necessarily your business to supervise that person, but you pay your income taxes, and the fact that he doesn't is annoying."

Taken together, these four categories of social allergens make living with someone else a challenge. But there could be more than mere repetition at stake here, Cunningham says. When a relationship starts and partners are in that dreamy love state, the other person is seen through rose-tinted glasses. It's not that you're unaware of your partner's habit of cracking his knuckles; it's just that it does not seem like a big deal. Later on, when what Cunningham calls deromanticization has taken place, the willingness to overlook these uncouth behaviors evaporates.

The second reason these social allergens become more annoying with time is they occur more frequently after the initial romantic blast. Psychologist Rowland S. Miller of Sam Houston State University has a good explanation: once a courtship is over and a partner has been won, people usually relax the crafting of their self-presentations and try less hard to make consistently favorable impressions. Thus it is that a suitor who never appeared for breakfast without his beard well trimmed and his cologne apparent becomes a spouse who shows up in his underwear, unwashed and unshaven, and then steals the last doughnut.

Men and women differ on which social allergens they are most likely to exhibit and which ones are

MAX OPPENHEIM *Getty Images*

The garrulous life of the party is also the performer who will not shut up.

the most likely to bug them. Men tend to see women as inconsiderate, intrusive, and increasingly domineering and controlling as a relationship progresses. Perhaps not surprisingly, women see men as more likely to exhibit uncouth behaviors. Women were more annoyed than men were with violations of societal expectations, such as smoking in no-smoking areas or ignoring parking tickets.

Most couples have noticed that the same behavior that drives you crazy when your partner does it can be (relatively) easy to ignore when someone outside the relationship does it. Cunningham sees two reasons for this. One is that if it is not your partner, you believe you are going to escape it. You can get through any dinner sitting next to an annoying person because you know that it will be over when you leave the table. Yet if your spouse has that same nettlesome trait, it will be present that night and at lunch the next day and on and on and on.

So what can you do? How can you prevent these social allergens from destroying your relationship? Cunningham says you should try to be accepting of your partner's irritating habits, even though this advice is likely to have the same effect on you as the admonition to "eat more fruits and vegetables." "This trait is a part of this person," he says. "You've got to take this if you want all of the other good things."

A slightly more practical approach is to try to reclassify behaviors. "You can see certain quirks that used to be annoying as actually endearing," Cunningham says. Unfortunately, this reclassification usually occurs posthumously. Your spouse's infuriating habit of snapping his bubble gum may seem oddly charming when the poor guy is remembered at his funeral. "If you can do that before the person has passed on, you're ahead of the game," he adds.

From Love to Loathing

Of course, we may be missing an angle here. There are times when, either consciously or unconsciously, we want to take a dig at our partners, says psychologist Arthur Aron of Stony Brook University. Aron says that sometimes we realize we are trying to get back at our partners for a transgression, and spouses know best what will get their partners' goat. "You know when you hang out with someone, don't bring up certain topics or, if you do, don't push it too hard," Aron says. "With spouses, we know that our partners know our hot buttons, and it's even more annoying when our partners bring them up."

Intentionality of action may factor significantly in the annoying quotient. A door slammed by the wind grates way less than a door slammed by an angry spouse. Aron believes that this intentional "pushing too hard" is not limited to adult relationships.

Aron says that children will deliberately not clean up their rooms, will drink milk directly from the container, and will not hand in their homework as a way to annoy a parent who sets a curfew too early or refuses to raise an allowance. Like Hatfield, Aron believes that many of these acts of defiance will be overlooked when there is commitment in a relationship and will be exaggerated when there is not. Growing annoyance can be a sign of trouble to come.

The good news here is that there are ways to tackle the problem. Aron says that one of the most important things you can do in a relationship is to celebrate when something good happens to your partner. "That's even more important than supporting him or her when things go bad," Aron says.

Another trick is to be sure to do novel, challenging and exciting things with your partner fairly often. Anything you do to make your relationship better will tend to make your partner less annoying. It's a case of a familiar aphorism turned on its head: "Mind the pounds, and the pennies will take care of themselves." M

(Further Reading)

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GETTY IMAGES

The Truth about Borderline Personalities

True sufferers are often troubled—and yet time and treatment can often improve their lives

BY SCOTT O. LILIENFELD AND HAL ARKOWITZ

THIS PAST JUNE renowned clinical psychologist Marsha M. Linehan of the University of Washington made a striking admission. Known for her pioneering work on borderline personality disorder (BPD), a severe and intractable psychiatric condition, 68-year-old Linehan announced that as an adolescent, she had been hospitalized for BPD. Suicidal and self-destructive, the teenage Linehan had slashed her limbs repeatedly with knives and other sharp objects and banged her head violently against the hospital walls. The hospital's discharge summary in 1963 described her as "one of the most disturbed patients in the hospital." Yet despite a second hospitalization, Linehan eventually improved and earned a Ph.D. from Chicago's Loyola University in 1971.

Many psychologists and psychiatrists were taken aback by Linehan's courageous admission, which received high-profile coverage in the *New York Times*. Part of their surprise almost surely stemmed from an uncomfortable truth: people with BPD are often regarded as hopeless individuals, destined to a life of emotional misery. They are also frequently viewed as so disturbed that they cannot possibly achieve success in everyday life. As a consequence, highly accomplished individuals such as Linehan do not fit the stereotypical mold of a former BPD sufferer. But as Linehan's case suggests, much of the intense pessimism and stigma surrounding this disorder are unjustified. Indeed, few psychological disorders are more mischaracterized or misunderstood.

Fuzzy Borders

New York psychoanalyst Adolf Stern coined the term "borderline" in 1938, believing this condition to lie on the murky "border" between neurosis and psychosis. The term was a misnomer because BPD bears little relation to most psychotic disorders. The name may have perpetuated a widespread misimpression that the disorder applies to people on the edge of psychosis, who have at best a tenuous grasp of reality. Not surprisingly, the popular conception of BPD, shaped by such films as the 1987 movie *Fatal Attraction* (featuring actress Glenn Close as a woman with the condition), is that of individuals who often act in bizarre and violent ways.

An error committed by some clinicians is presuming that patients who do not respond well to treatment or who are resistant to therapists' suggestions are frequently "borderlines." Some mental health workers even seem to habitually attach the label "borderline" to virtually any client who is extremely difficult to deal with. As Harvard University psychiatrist George Valliant observed in a 1992 article, the BPD diagnosis often reflects clinicians' frustrated responses to challenging patients.

In reality, BPD is meant to apply to a specific subgroup of individuals who are emotionally and interpersonally unstable. Indeed, Linehan has argued that a better name for the condition is "emotion dysregulation disorder." Much of the everyday life of individuals with BPD is an emotional roller coaster. Their moods often careen wildly from normal to sad or hostile at the slightest provocation. As Linehan pointed out in a 2009

COURTESY OF SCOTT O. LILIENFELD (*Lilienfeld*); COURTESY OF HAL ARKOWITZ (*Arkowitz*); STUART BRADFORD (*illustration*)

interview with *Time* magazine, "Borderline individuals are the psychological equivalent of third-degree-burn patients. They simply have, so to speak, no emotional skin." Their perceptions of other people are inconsistent, and they often vacillate between worshipping their romantic partners one day and detesting them the next. Their identity is similarly unstable; patients may lack a clear sense of who they are. And their impulse control is poor; they are prone to explosive displays of anger toward others—and themselves. [For more on the symptoms, causes and treatment of BPD, see "When Passion Is the Enemy," by Molly Knight Raskin; SCIENTIFIC AMERICAN MIND, July/August 2010.]

Further fueling the stigma attached to BPD is the assumption that nearly all individuals who engage in self-cutting, such as wrist slashing, are so-called borderlines. In fact, in a 2006 study of 89 hospitalized adolescents who engaged in cutting and related forms of nonsuicidal self-injury, Harvard psychologist Matthew Nock and his colleagues found that 48 percent did not meet criteria for BPD. The lion's share of these individuals exhibited other personality disorders, such as avoidant personality disorder, which is associated with a pronounced fear of rejection.

Once Borderline Always Borderline?

Two allied myths about BPD are that patients virtually never improve over time and are essentially untreatable. Yet a number of recent studies indicate that many patients with BPD shed their diagnoses after several years. In a 2006 investigation, for example, psychologists C. Emily Durbin and Daniel N. Klein, both then at Stony Brook University, found that although 16 percent of 142 psychiatrically disturbed adults initially met criteria for BPD, only 7 percent did after a decade. Moreover, the average levels of BPD symptoms in the sample declined significantly over time. Work by psychologist Timothy J. Trull and his colleagues at the University of Missouri–Columbia similarly suggests that many young adults who display some features of BPD do not exhibit these features after only a two-year period, indicating that early signs of BPD often abate.

> Studies indicate that many patients with borderline personality disorder **shed their diagnoses after several years**.

BPD is not easy to treat. Yet Linehan has shown that an intervention she calls "dialectical behavior therapy" (DBT) is modestly helpful to many sufferers of the condition. DBT encourages clients to accept their painful emotions while acknowledging that they are unhealthy and need help. It teaches patients specific coping skills, such as mindfulness (observing their own thoughts and feelings nonjudgmentally), tolerating distress and mastering negative emotions. Controlled studies, reviewed by Duke University psychologist Thomas R. Lynch and his colleagues in 2007, indicate that DBT somewhat reduces the suicidal and self-destructive behaviors of patients. Lynch and his collaborators also found that DBT may lessen feelings of hopelessness and other symptoms of depression. Still, DBT is not a panacea, and no clear evidence exists that DBT can stabilize patients' identity or relationships. Preliminary but promising data suggest that certain medications, including such mood stabilizers as Valproate, can alleviate the interpersonal and emotional volatility that characterize BPD, according to a 2010 review by psychiatrist Klaus Lieb of University Medical Center in Mainz, Germany, and his colleagues.

A Continuing Challenge

Not all BPD patients improve on their own or with treatment, and even those who do typically continue to battle the demons of emotional and interpersonal volatility. Nevertheless, the extreme negative views of this condition are undeserved, as is the mislabeling of a wide swath of the psychiatric population as borderline. It is also undeniable that many clinicians must become more judicious in their use of the BPD label and avoid attaching it to virtually any patient who is oppositional or unresponsive to treatment.

Fortunately, there is room for cautious optimism. As psychiatrist Len Sperry of Barry University noted in a 2003 review, BPD is the most researched of all personality disorders, a fact that remains true today. The fruits of that work promise to yield an improved understanding of BPD, which may reduce the stigma surrounding this widely misunderstood diagnosis. If so, perhaps the day will soon come when successful people who once struggled with BPD, such as Marsha Linehan, are no longer perceived as exceptions that prove the rule. **M**

SCOTT O. LILIENFELD and HAL ARKOWITZ serve on the board of advisers for *Scientific American Mind*. Lilienfeld is a psychology professor at Emory University, and Arkowitz is a psychology professor at the University of Arizona.

Send suggestions for column topics to editors@SciAmMind.com

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Two Faces of Death

Our dueling existential minds influence our beliefs and behaviors in different ways

BY WRAY HERBERT

THE THOUGHT of shuffling off our mortal coil can make all of us a little squeamish. But avoiding the idea of death entirely means ignoring the role it can play in determining our actions. Consider the following scenario:

> *You're visiting a friend who lives on the 20th floor of an old inner-city apartment building. It's the middle of the night when you are suddenly awakened from a deep sleep by the sound of screams and the choking smell of smoke. You reach over to the nightstand and turn on the light. You are shocked to find the room filling fast with thick clouds of smoke. You run to the door and reach for the handle. You pull back in pain as the intense heat of the knob scalds you violently. Grabbing a blanket off the bed and using it as protection, you manage to turn the handle and open the door. Almost immediately a huge wave of flame and smoke roars into the room, knocking you back and literally off your feet. There is no way to leave the room. It is getting very hard to breathe, and the heat from the flames is almost unbearable. Panicked, you scramble to the only window in the room and try to open it. As you struggle, you realize the old window is painted shut around all the edges. It doesn't budge. Your eyes are barely open now, filled with tears from the smoke. You try calling out for help, but the air to form the words is not there. You drop to the floor, hoping to escape the rising smoke, but it is too late. The room is filled top to bottom with thick fumes and is nearly entirely in flames. With your heart pounding, it suddenly hits you, as time seems to stand still, that you are literally moments away from dying. The inevitable unknown that was always waiting for you has finally arrived. Out of breath and weak, you shut your eyes and wait for the end.*

Yipes! What an excruciating and terrifying way to go. If you're like me, you experienced a moment of panic reading that passage. But relax—you're okay. The above scenario is just an experimental manipulation, one meant to jump-start your existential mind.

Or one of your two existential minds—if an emerging theory is correct. Psychological scientists Laura E. R. Blackie and Philip J. Cozzolino of the University of Essex in England have been exploring the idea that we are all governed by two disparate existential systems, each with its own distinct method of processing the idea of death. Both existential minds have the power to meaningfully change our attitudes and actions, but they work in very different—almost opposite—ways.

Of Two Minds

One of our systems of existential thinking responds to the abstract concept of dying, so that even subtle everyday reminders of death, such as driving past a cemetery, prime the mind to ward off existential terror. This system tends to bolster our already existing beliefs, both religious and cultural, as a way of affirming life. For instance, studies have shown that after people reflect on what will happen when they die, they become more nationalistic and defensive about their political beliefs.

The second existential system is vivid, concrete and highly personal; it is triggered not by subtle and abstract thoughts but by actually coming face to face with death. When this system is primed into action—as the above apartment fire scenario is meant to do—our very personal sense of mortality can lead us to reexamine our priorities in life, to become more grateful and to grow spiritually. Soldiers who have seen combat and people who have lived through life-threatening illnesses often report these shifts in attitude.

Priority Shifts

Therefore, some thoughts of death shore up our beliefs, and other types of reflection make us reexamine them. Which kind leads to a better life? For their experiment, Blackie and Cozzolino recruited volunteers aged 17 to 76 and primed them in different ways. Some answered open-ended questions about death, to remind them of their mortality in a general way, whereas others imagined they were trapped and dying in the burning apartment by reading the paragraph above. Another group, the control subjects, thought about going to the dentist—unpleasant but not life-threatening. Then they all read one of two fake news stories. One story said that blood donations were at "record lows" and thus the need for blood donations was high. The other said the opposite, that supplies were at "record highs," so the need for donations was low. Finally, the researchers gave all the participants the opportunity to volunteer as blood donors.

The scientists were hoping to see which group became more altruistic,

Our **sense of mortality** can lead us to reexamine our priorities in life, to become more grateful and to grow spiritually.

MATT MENDELSON

Those who were vividly primed by **thoughts of their death** were willing to give blood whether the need was high or low.

LINO

and they succeeded. The findings were an interesting mix. Those primed in an abstract way by general thoughts about dying were more generous than the dentist-imagining controls, but only when the need was high. This result suggests that the abstract thinkers were reaffirming the societal expectation that it is good to give to the needy—not exactly a sweeping personal epiphany.

Those who were vividly primed by thoughts of their own death in flames, however, were even more generous than those primed in a more subtle and abstract way. They were willing to give blood whether the need was high or low, suggesting they had undergone a fundamental reexamination of their values.

Why would this difference exist? One possibility, as the scientists write in the online version of the journal *Psychological Science*, is that our abstract existential system has no tolerance for the gory details of death; in fact, abstract thoughts of death generate an aversion to bodily fluids, including blood. Indeed, previous experiments have supported this idea: after being reminded of their mortality, people are more squeamish about physical trauma. In the current study this aversion to blood was not strong enough to trump the cultural expectation that we should help those in need—but it carefully meted out generosity to those truly in the most need.

People who have come close to perishing, on the other hand, see things differently. For them, blood is not something aversive at all—it is the stuff of life. M

For more insights into the quirks of human nature, visit the "We're Only Human. . ." blog and podcasts at www.psychologicalscience.org/onlyhuman

WRAY HERBERT is writer in residence at the Association for Psychological Science.

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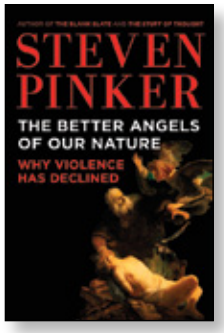
books

AN END TO WAR?

The Better Angels of Our Nature: Why Violence Has Declined

by Steven Pinker. Viking Adult, 2011 ($40)



According to the Stockholm International Peace Research Institute (SIPRI), worldwide military expenditures have been growing annually for the past 15 years, and between 15 and 20 major armed conflicts—yes, wars—are in progress as you read this. All told, upward of 175 million people died in war-related violence during the 20th century, plus another eight million because of conflicts among individuals.

Even so, according to this weighty new book by Harvard University psychologist Steven Pinker, the "better angels" of human nature have actually brought about a dramatic reduction in violence during the past few millennia. Yes, the absolute number of victims has been rising, but relative to the world's population, the numbers look good.

The shift toward nonviolence, he says, has been driven by many factors, such as the spread of agriculture and the rise of feminism and democracy. Such trends have led to a reduction in institutionalized torture and execution and slavery and, especially in recent years, to an increase in the rights of women, homosexuals, children and animals.

Pinker acknowledges that one's immediate experience belies these facts to the point where you might even want to call him "hallucinatory." Yet the wealth of data he presents cannot be ignored—unless, that is, you take the same liberties as he sometimes does in his book. In two lengthy chapters, Pinker describes psychological processes that make us either violent or peaceful, respectively. Our dark side is driven by a evolution-based propensity toward predation and dominance. On the angelic side, we have, or at least can learn, some degree of self-control, which allows us to inhibit dark tendencies.

There is, however, another psychological process—confirmation bias—that Pinker sometimes succumbs to in his book. People pay more attention to facts that match their beliefs than those that undermine them. Pinker wants peace, and he also believes in his hypothesis; it is no surprise that he focuses more on facts that support his views than on those that do not. The SIPRI arms data are problematic, and a reader can also cherry-pick facts from Pinker's own book that are inconsistent with his position. He notes, for example, that during the 20th century homicide rates failed to decline in both the U.S. and England. He also describes in graphic and disturbing detail the savage way in which chimpanzees—our closest genetic relatives in the animal world—torture and kill their own kind.

Of greater concern is the assumption on which Pinker's entire case rests: that we look at relative numbers instead of absolute numbers in assessing human violence. But why should we be content with only a relative decrease? By this logic, when we reach a world population of nine billion in 2050, Pinker will conceivably be satisfied if a mere two million people are killed in war that year.

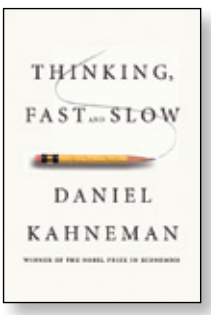
The biggest problem with the book, though, is its overreliance on history, which, like the light on a caboose, shows us only where we are not going. We live in a time when all the rules are being rewritten blindingly fast—when, for example, an increasingly smaller number of people can do increasingly greater damage. Yes, when you move from the Stone Age to modern times, some violence is left behind, but what happens when you put weapons of mass destruction into the hands of modern people who in many ways are still living primitively? What happens when the unprecedented occurs—when a country such as Iran, where women are still waiting for even the slightest glimpse of those better angels, obtains nuclear weapons? Pinker doesn't say.

—Robert Epstein

COGNITIVE ILLUSIONS

Thinking, Fast and Slow

by Daniel Kahneman. Farrar, Straus and Giroux, 2011 ($30)



Daniel Kahneman and Amos Tversky, two of psychology's most venerable figures, used to joke that their area of expertise, decision making, was one their grandmothers already knew well. Luckily for us, their grandmothers must have been extremely clever ladies.

Take the concept that losses affect us more than gains, which the two men established. Although this idea may seem obvious, its consequences are not. For example, an analysis of 2.5 million putts in professional golf revealed that, regardless of the difficulty of the shot, players were more successful when striving for par than for one stroke under par. That is, the distaste for not reaching this benchmark motivated the golfers more than the desire to beat it, leading them to concentrate harder on nailing their next putt.

Now consider how a person's aversion to loss might affect a territory battle, a corporate restructuring or attempts to trim costs. Any reform will involve winners and losers; however, the underdogs will be more driven to fight against change and will inevitably temper the outcomes. Score one for the losers.

In *Thinking, Fast and Slow,* Kahneman, a Nobel Prize winner and professor emeritus at Princeton University, sets these findings and others in a broad model of the mind. Kahneman explains that humans evolved decision-making shortcuts to aid in survival; avoiding losses is one example. Often we can mediate these gut reactions with logical reasoning. Even so, the brain frequently runs up against its limits, leading to flaws in our thinking.

Knowing how those errors arise can come in handy in numerous fields, including health care. In one study, Kahneman's subjects placed a hand in icy water for 60 seconds and 90 seconds. After a minute elapsed in the 90-second trial, the experimenter silently warmed the water by one degree. When asked later which episode they would rather repeat, the participants paradoxically chose the longer one.

The subjects, it seems, recalled the *average* of their peak pain over the trial's duration, which was lower in the 90-second case, rather than the overall

MORAL MAYHEM

The Righteous Mind: Why Good People Are Divided by Politics and Religion

by Jonathan Haidt. Pantheon Books, 2012 ($28.95)

In a world where people draw lines in the sand between religions and the vitriolic waters of politics make islands of ideologies, Jonathan Haidt's new book, *The Righteous Mind,* offers a glimpse of hope.

According to Haidt, a professor of social psychology at the University of Virginia, logic is not a suitable guide for interpreting moral issues. To better explain the relation between our moral inclinations and conscious thought, he uses the metaphor of an elephant and its rider. The bulky elephant, which signifies our emotions, makes the first decisive moves along a moral trajectory. The rider, who embodies reason, attempts to steer the giant beast by concocting justifications for the new course. Understanding that our emotions are in control, Haidt believes, will help bridge the gap between groups with conflicting ideas.

Throughout the book, Haidt broadens the definition of morality to clarify why polarized groups, such as religious conservatives and atheists or Democrats and Republicans, often fail to see eye to eye. Morality, Haidt says, is not solely about fairness and preventing harm; it also incorporates notions such as liberty, loyalty and authority, and it serves to create bonds between people.

In the political realm, Haidt presents research to explain why Republicans and Democrats diverge as much as they do. Democrats care more about harm and fairness when making moral decisions than loyalty, authority or sanctity. Republicans, on the other hand, are better able to interweave these moral threads. Understanding that our feelings guide our behavior and that political adversaries have different emotional triggers, he writes, will help both groups come to terms with each other.

As for spirituality, Haidt argues that religions are ultimately less about believing in a higher power than about forming bonds with others and being part of something larger than oneself. To illustrate, Haidt draws parallels between religious groups and fans who pack college football games every week adorned in team colors, locked arm in arm and singing fight songs with their brethren. People are built to seek membership in a like-minded community, he attests, be it a Sunday church service or a stadium.

Though at times highly philosophical, Haidt's book is a must-read if you want to understand how conflicts arise—and how we might prevent them. *—Brian Mossop*

quantity of pain. They also remembered the end of each experience most vividly. Thus, Kahneman suggests that if the goal is to reduce the memory of pain, medical workers might prioritize softening a procedure's worst moment over shortening it. Such studies led Kahneman, famous for bridging psychology and economics, to begin crafting a model of how we evaluate our happiness.

The writing takes on a tender tone when he describes his longtime collaboration with Tversky, who died in 1996. For years they spent their afternoons in conversation, thinking up deceptive scenarios and examining each other's decisions. Kahneman writes in much the same way: almost every other page includes a thought experiment to elicit the reader's judgments. Stumbling into your own sloppy thinking makes their discoveries all the more personal.

—Sandra Upson

Coming in March/April 2012

Who's in Charge?: Free Will and the Science of the Brain *by Michael S. Gazzaniga* A leading cognitive neuroscientist marshals recent research to argue that we possess agency. **Read it now:** ScientificAmerican.com/Mind/mar2012/free-will

The Journal of Best Practices: A Memoir of Marriage, Asperger Syndrome, and One Man's Quest to Be a Better Husband *by David Finch* The author sets out to master the quirks of his condition.

The Age of Insight: The Quest to Understand the Unconscious in Art, Mind, and Brain, from Vienna 1900 to the Present *by Eric R. Kandel* A Nobel Prize winner takes readers to his birthplace to trace the origins of big ideas in brain science, literature and art.

Dirty Minds: How Our Brains Influence Love, Sex, and Relationships *by Kayt Sukel* A journalist explores the neuroscience of love and sex.

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(*3*) Free or nominal rate copies mailed at other classes mailed through the USPS: average number of copies each issue during preceding 12 months, 0; number of copies of single issue published nearest to filing date, 0. (*4*). 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askthe**Brains**

Is there a difference between the brain of an atheist and the brain of a religious person?

—**Emma Schachner**, Utah

Andrew Newberg, *director of research at the Myrna Brind Center of Integrative Medicine at Thomas Jefferson University and Hospital in Philadelphia, responds:*

RESEARCHERS HAVE pinpointed differences between the brains of believers and nonbelievers, but the neural picture is not yet complete.

Several studies have revealed that people who practice meditation or have prayed for many years exhibit increased activity and have more brain tissue in their frontal lobes, regions associated with attention and reward, as compared with people who do not meditate or pray. A more recent study revealed that people who have had "born again" experiences have a smaller hippocampus, a part of the brain involved in emotions and memory, than atheists do. These findings, however, are difficult to interpret because they do not clarify whether having larger frontal lobes or a smaller hippocampus causes a person to become more religious or whether being pious triggers changes in these brain regions.

Various experiments have also tried to elucidate whether believing in God causes similar brain changes as believing in something else. The results, so far, show that thinking about God may activate the same parts of the brain as thinking about an airplane, a friend or a lamppost. For instance, one study showed that when religious people prayed to God, they used some of the same areas of the brain as when they talked to an average Joe. In other words, in the religious person's brain, God is just as real as any object or person.

Thinking about God may activate the same parts of the brain as thinking about a friend or a lamppost.

Research also suggests that a religious brain exhibits higher levels of dopamine, a hormone associated with increased attention and motivation. A study showed that believers were much more likely than skeptics to see words and faces on a screen when there were none, whereas skeptics often did not see words and faces that were actually there. Yet when skeptics were given the drug L-dopa, which increases the amount of dopamine in the brain, they were just as likely to interpret scrambled patterns as words and faces as were the religious individuals.

So what does the research mean? At the moment, we do not have a clear way to connect all the dots. For now we can say that the religious and atheist brains exhibit differences, but what causes these disparities remains unknown.

How do our thoughts influence our physical sensations?

—**Davide Razzoli**, Italy

Jeannine Stamatakis, *an instructor at several colleges in the San Francisco Bay Area, explains:*

YOU MAY have noticed that when you think positively, you tend to feel more relaxed and energetic. When you are upset, you are more likely to feel tired and lazy. These sensations are not coincidental. The way we think—our attitudes and outlook on life—strongly affects our physical state.

The endocrine system, a network of glands that secretes different hormones into the bloodstream, is the powerhouse that regulates our moods. The feelings you associate with being angry, for example, arise from the stress hormones, such as cortisol and norepinephrine, that your brain releases on registering indignation. These hormones release stored energy and increase the amount of blood flowing to your muscles, which in turn elevates your heart rate, blood pressure and breathing while shutting down key metabolic processes, such as digestion and growth.

Similarly, endorphins alter your happiness. An endorphin release causes a natural high, commonly known as an endorphin rush or a runner's high. This high is associated with elevated mood and reduced pain. A brain-imaging experiment by neuroscientist Henning Boecker of the University of Bonn in Germany showed that after highly conditioned male athletes completed two hours of endurance running, they exhibited elevated levels of endorphins in their brain and that an increase in these hormones was associated with the runners' intense feelings of euphoria.

In short, making an effort to think positively, even if doing so feels like a strain, is vital to keeping your body healthy. Take the uplifting example of Norman Cousins, former editor of the now defunct *Saturday Review*. Cousins was told that he had ankylosing spondylitis, a painful and degenerative spine disease that typically affords sufferers a one-in-500 chance of survival. His doctor predicted that he had six months to live, but Cousins refused to accept the diagnosis. He surrounded himself with family and friends, watched numerous comedy films and sought out positive affirmations. Cousins ended up beating the odds and lived 26 years after his diagnosis. Although it is impossible to know whether his survival hinged on his positive thinking rather than genetic or medical factors, Cousins's case suggests that an intensely optimistic outlook can help alter physical health. M

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

JAMIE CARROLL /iStockphoto

Head Games

Match wits with the Mensa puzzlers

1 SENTENCE SNAKE

Start at any letter and move in any direction to find the coiled phrase that completes this rhyme. There is one null letter that must be skipped.

DON'T CHANGE HORSES, IT IS SAID;

F	I	H	H	W
N	T	E	O	?
E	V	R	S	D
T	E	E	I	A
O	N	S	D	E

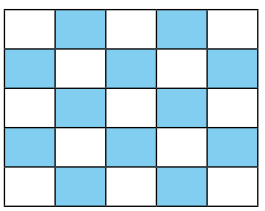
2 HAPPY BIRTHDAY

A woman muses on her age: "The day before yesterday I was 29, but next year I'll be 32." There is only one day in the year that her statement could be true. What day is it?

3 WORD SQUARE

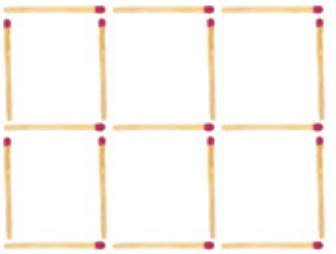
Create a five-letter word square, which reads the same across and down, from the following definitions (not necessarily in order):

- **The edge of an ocean, lake or pond**
- **A little island**
- **Part of the ears**
- **Tries out**
- **Upright, straight**



4 MEET YOUR MATCH

Remove five matchsticks from the design below so that only three squares remain.



5 A RAPID EDUCATION

Change FOOL to WISE in only six steps, changing one letter at a time and making a valid English word at each step.

FOOL

_____

_____

_____

_____

_____

WISE

6 ODD MAN OUT

Unscramble the words below. Which one does not belong in the group?

TTOOORN MMAII TTELESA CPNOEAGHNE

7 ANAGRAM

Fill the blanks by rearranging the same seven letters to make three different words.

The aristocratic _ _ _ _ _ _ _ was furious. He said, "I am _ _ _ _ _ _ _ that the security I have hired cannot protect me from the deranged soldier who is wandering around my castle with a _ _ _ _ _ _ _."

8 DEEP DISCOUNTS

Two men were comparing their purchases at the discount store. One had bought pairs of socks in packages of three for $1.00, and the other had bought socks marked "Eight pairs for $2.50." Obviously, the eight for $2.50 were a better deal, and that buyer gloated that he had paid 50 cents less on his total purchase than had his friend. How many pairs of socks had they each bought?

9 BEAN COUNTERS

Three friends entered a contest in which they had to guess the number of beans in a jar. In this case, it was a very small jar: Ann thought there were 43, Becky guessed 34 and Clarissa settled on 41. One of them was off by six, another by three and the third by only one. How many beans were in the jar?

Answers

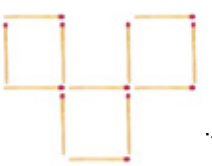
1. NOT EVEN IF THE HORSE IS DEAD?

2. January 1. (The woman's birthday is December 31. The day before yesterday she was 29; yesterday she turned 30. Later this year she will turn 31, and next year she will turn 32.)

3.

I	S	L	E	T
S	H	O	R	E
L	O	B	E	S
E	R	E	C	T
T	E	S	T	S

4.



5. FOOL, WOOL, WOOD, WOLD, WILD, WILE, WISE. (There may be other ways.)

6. COPENHAGEN. The others are TORONTO, MIAMI and SEATTLE, all of which are North American cities.

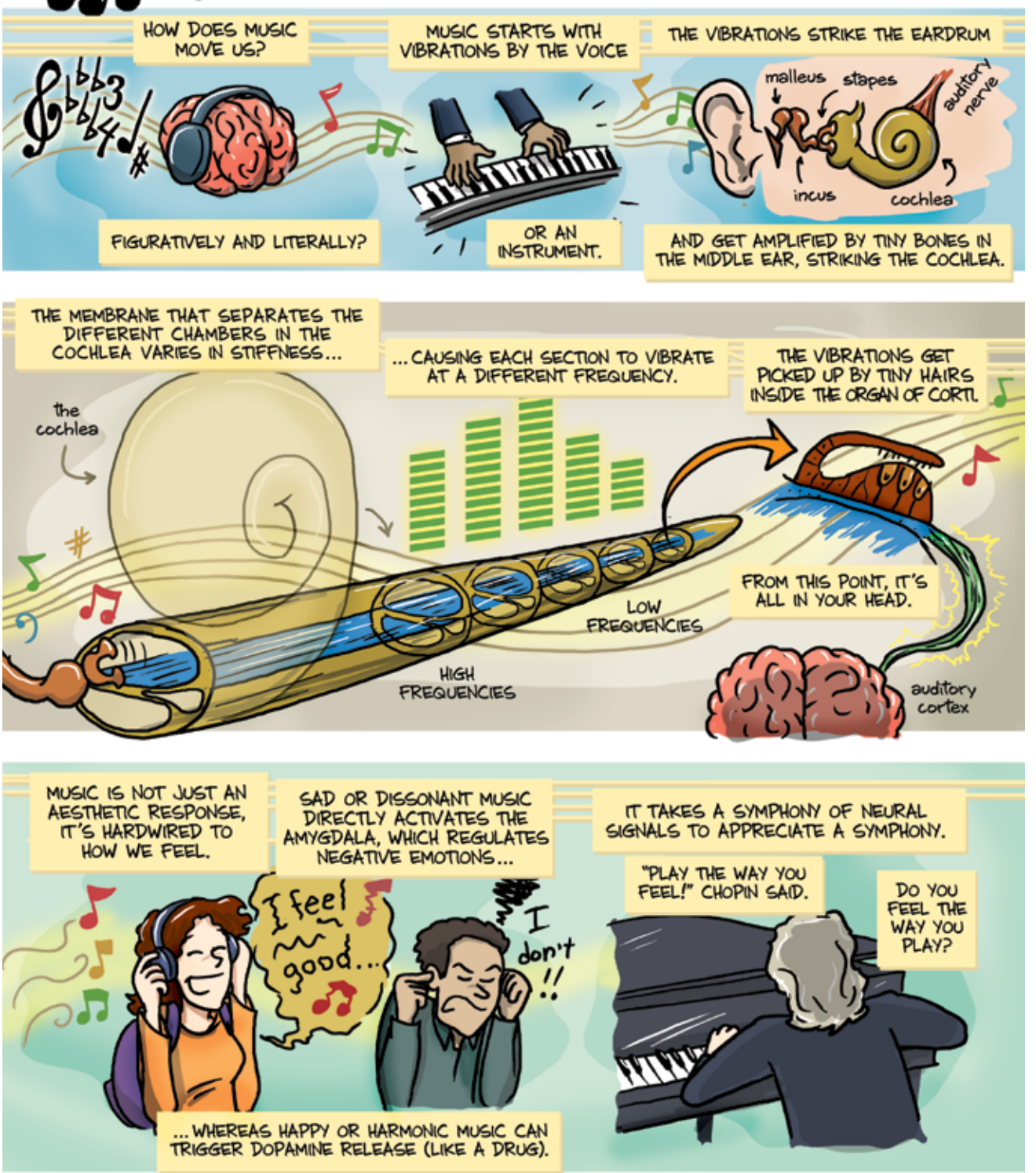
7. Grandee, angered (or enraged), grenade.

8. 24 pairs each.

9. 40 beans.

Music to your Brain

BY DWAYNE GODWIN AND JORGE CHAM



Dwayne Godwin is a neuroscientist at the Wake Forest University School of Medicine. Jorge Cham draws the comic strip Piled Higher and Deeper *at www.phdcomics.com.*

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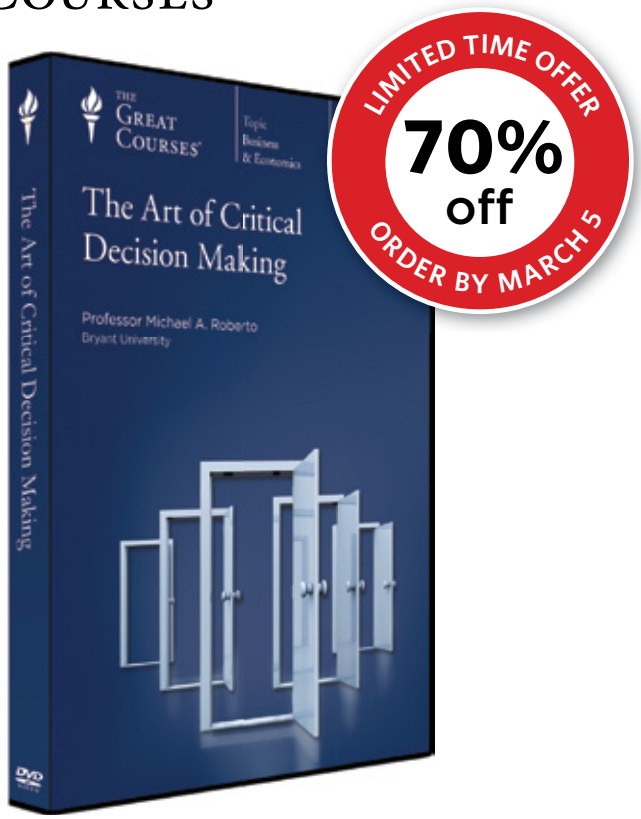

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