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SCIENTIFIC AMERICAN
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Sampling of Topics

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- SOLAR SCIENCE
- COGNITIVE NEUROSCIENCE
- ALPINE ARCHAEOLOGY

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Connect to the science community on Bright Horizons 14. Inhale Alaska's unabashed outdoorsy spirit. Enjoy Native art and historic places. Sample unrivaled birdwatching. Glimpse bears on the beach and whales in the waves. Share glacier-watching and hot cocoa with a friend. Bring home the latest in the world of science.

Sampling of Topics

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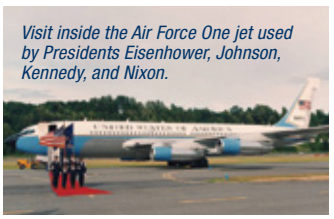
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SCIENTIFIC AMERICAN MIND
Volume 22, Number 5, November/December 2011

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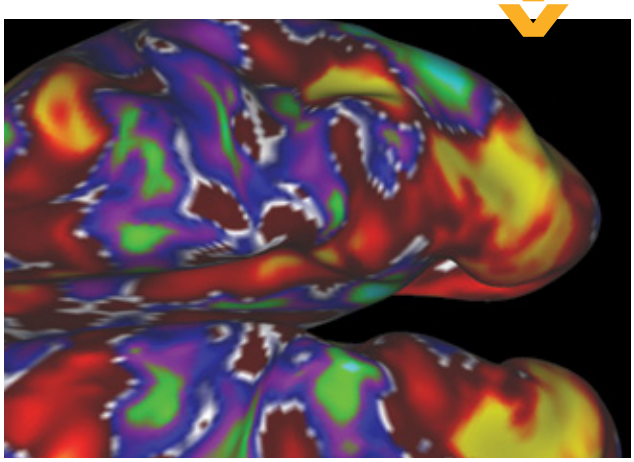

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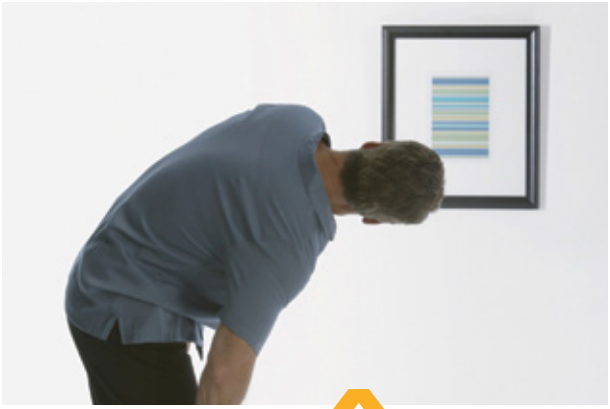

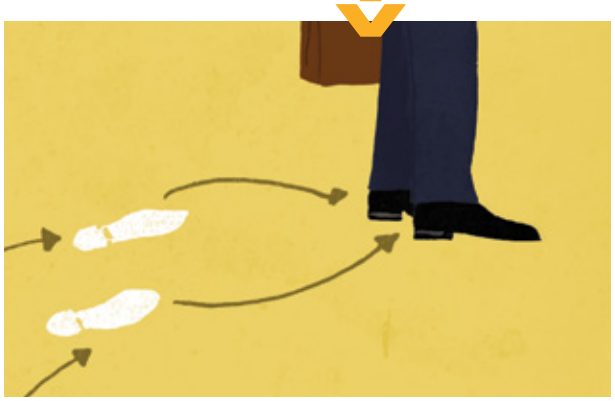

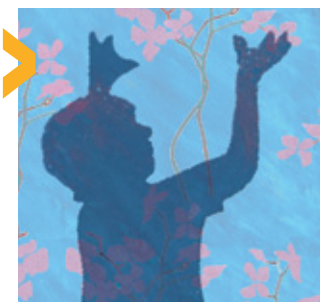

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Sparks in Your Sleep

Inspiration often seems to pop up unpredictably—in the shower, on a long walk or even at the grocery store. But one place I never expect it is during sleep. I tend to think of myself as a computer: at bedtime I power myself down with teeth brushing and pillow fluffing, and soon enough my brain switches off.

That analogy, however, is dead wrong. Your sleeping brain has simply entered an alternative mode of thinking, as psychologist Deirdre Barrett writes in "Answers in Your Dreams," on page 26. With your eyes closed and limbs immobilized, your brain spins fanciful webs of ideas that your waking mind might have filtered out. In that rich environment, your creativity and problem-solving skills can blossom.

You can even sometimes steer the course of a dream. Along with the high entertainment value of, say, suddenly gaining the ability to fly, this control could prove useful for overcoming anxiety and other troubles, as psychologist Ursula Voss explains in "Unlocking the Lucid Dream," on page 33.

Dreaming is not the only state the brain inhabits outside the boundaries of our awareness. Even when you sit quietly doing nothing, your brain bustles with activity. Groups of neurons continue to fire unbidden, forming patterns of activity that neuroscientists are now using to produce stunning maps of the mind. *Scientific American Mind*'s Ann Chin and I collaborated to bring you "Head Shots," on page 42.

As you take in those colorful images, reflect for a moment on the marvel of your eyes—another example of how the brain works behind the scenes. When your eyes focus, they do not zero in on one spot: they actually dart around, using tiny subconscious movements called microsaccades. These motions keep your vision healthy, but they can also reveal your hidden desires, as Susana Martinez-Conde and Stephen L. Macknik write in "Shifting Focus," on page 48. Paradoxically enough, although we strive—and sometimes manage—to control our thoughts and actions, our brain often seems to have a mind of its own.

Sandra Upson
Managing Editor
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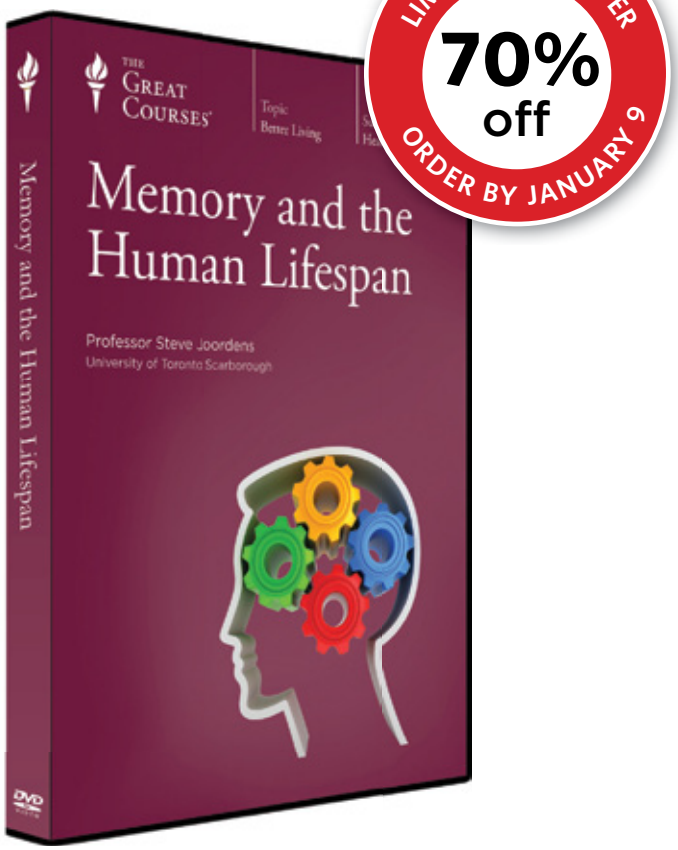

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While many of us think of human memory as just a way to call up facts or episodes from our pasts, the truth is that it is much, much more. Your various memory systems, in fact, create the ongoing narrative that makes your life truly *yours*. Without them, you wouldn't be able to make decisions, learn, or even form a personality that sets you apart from others.

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MIRROR THERAPY

I read with great pleasure "Reflections on the Mind," by Vilayanur S. Ramachandran and Diane Rogers-Ramachandran [Illusions]. These experiments involving the senses are indeed fascinating. Similar experiments were first done by a well-known behavioral optometrist, Robert A. Kraskin, more than 40 years ago in Washington, D.C. He used the techniques in diagnosis and for vision rehabilitation—including for Luci Baines Johnson while her father was in office. He called his regimen of eye exercises "squinchel" and taught it to many optometrists and vision therapists nationwide at various professional meetings and workshops. As a member of the advisory board of the Neuro-Optometric Rehabilitation Association, I thank you for bringing this useful and interesting phenomenon back into public awareness.

Diana P. Ludlam
via e-mail

MIND-SET ISN'T EVERYTHING

"Painful Pessimism," by Janelle Weaver [Head Lines], is misleading: most drugs are taken to effect a cure, but the study was only on pain management. It has long been known that pain management is very complex and involves both physical and psychological factors. My wife has ovarian cancer, so I have become very aware of how many people truly believe that a positive attitude is the key to a cure. It ain't necessarily so! We have had drugs fail totally when we expected them to work, and vice versa. Please, please, please, *Scientific American Mind,* don't feed the antiscience, antipharma sentiment.

"Daouda"
commenting at
www.ScientificAmerican.com/Mind

PONDERING PORN

Melinda Wenner Moyer's article "The Sunny Side of Smut" [Perspectives] misleads readers by painting a "sunny" and innocuous picture of pornography. Not only does Moyer's account leave out much research that depicts pornography in bleaker terms, it also overstates the sunniness of porn. The overall insinuation one gets from the article is that porn is not all that bad.

When children are in porn, no one simply looks at the declining rates of child sexual abuse and blithely insinuates that child pornography has a "sunny" side to it. There it is acknowledged that the children depicted in child pornography (mainly girls) are harmed in its creation. Nonchild pornography is still a form of prostitution (paying women for sex acts), and there is ample evidence that women are harmed in systems of prostitution. Pointing to those who claim they were not harmed does not erase the harm of those who claim they were.

To indicate that porn does not harm relationships, Moyer looks at studies that take the porn users' side of the equation (their reports of sexual satisfaction and intimacy), as if that is sufficient to indicate that relationships are not harmed by porn. She ignores other research that indicates wives and girlfriends report being deeply hurt by their boyfriends' or husbands' porn use.

Finally, I think the "benevolent sexism" Moyer indicates that pornography produces hardly compensates for the "more negative attitudes toward women" that she concedes it brings about.

Saffy Casson
via e-mail

(perspectives)

The Sunny Side of Smut

For most people, pornography use has no negative effects—and it may even deter sexual violence

BY MELINDA WENNER MOYER

IT USED TO BE TOUGH to get porn. Renting an X-rated movie required sneaking into a roped-off room in the back of a video store, and eyeing a centerfold meant facing down a store clerk to buy a pornographic magazine. Now pornography is just one Google search away, and much of it is free. Age restrictions have become meaningless, too, with the advent of social media—one teenager in five has sent or posted naked pictures of themselves online, according to the National Campaign to Prevent Teen and Unplanned Pregnancy.

With access to pornography easier than ever before, politicians and scientists alike have renewed their interest in deciphering its psychological effects. Certainly pornography addiction or overconsumption seems to cause relationship problems [see "Sex in Bits and Bytes," by Hal Arkowitz and Scott O. Lilienfeld; SCIENTIFIC AMERICAN MIND, July/August 2010]. But what about the more casual exposure typical of most porn users? Contrary to what many people believe, recent research shows that moderate pornography consumption does not make users more aggressive, promote sexism or harm relationships. If anything, some researchers suggest, exposure to pornography might make some people *less* likely to commit sexual crimes.

Does Porn Harm Women?

The most common concern about pornography is that it indirectly hurts women by encouraging sexism, raising sexual expectations and thereby harming relationships. Some people worry that it might even incite violence against women. The data, however, do not support these claims. "There's absolutely no evidence that pornography does anything negative," says Milton Diamond, director of the Pacific Center for Sex and Society at the University of Hawaii at Manoa.

"It's a moral issue, not a factual issue."

In 2007 researchers at the University of Zagreb in Croatia surveyed 650 young men about their pornography use and sex lives. As they reported in the *Archives of Sexual Behavior*, the scientists found that users of mainstream, nonviolent pornography were neither more nor less sexually satisfied than nonusers. Both groups felt the same degree of intimacy in their current or recent relationships and shared the same range of sexual experiences. But when it came to violent or fetishist porn, the groups diverged. Consumers of these types of pornography appeared to masturbate more frequently, have more sexual partners over the course of their life, and experience slightly less relationship intimacy than their nonviolent porn-viewing counterparts.

Regular pornography use does not seem to encourage sexism, either. In 2007 Alan McKee, a cultural studies expert at the Queensland University of Technology in Australia, designed a questionnaire to assess sexist tendencies. He enclosed his survey in shipments of pornographic material distributed by a mail-order company and also posted it online. Responses from 1,023 pornography users indicated that the amount of pornography the subjects consumed did not predict whether they would hold negative attitudes toward women. The survey respondents who were most sexist were generally older men who voted for a right-wing political party, lived in a rural area and had a lower level of formal education.

But the questionnaire may have missed a key nuance. In a study published in 2004 in the *Journal of Psychology & Human Sexuality*, researchers at Texas Tech University administered a different survey to male and female college students and found that although consumers of pornography did not display more negative attitudes toward women, they were more likely than other respondents to believe that women should be protected from harm—what the investigators call "benevolent sexism."

Self-Medicating with Fantasy

Perhaps the most serious accusation against pornography is that it incites sexual aggression. But not only do rape statistics suggest otherwise, some experts believe the consumption of pornography may actually reduce the desire to rape by offering a safe, private outlet for deviant sexual desires.

"Rates of rapes and sexual assault in the U.S. are at their lowest levels since the 1960s," says Christopher J. Ferguson, a professor of psychology and criminal justice at Texas A&M International University. The same goes for other countries: as access to pornography grew in once restrictive Japan, China and Denmark in the past 40 years, rape statistics plummeted. Within the U.S., the states with the least Internet access between 1980 and 2000—and therefore the least access to Internet pornography—experienced a 53 percent increase in rape incidence, whereas the states with the most access experienced a 27 percent drop in the number of reported rapes, according to a paper published in 2006 by Anthony D'Amato, a law professor at Northwestern University.

It is important to note that these associations are just that—associations. They do not prove that pornography is the cause of the observed crime reductions. Nevertheless, the trends "just don't fit with the theory that rape and sexual assault are in part influenced by pornography," Ferguson explains. "At this point I think we can say the evidence just isn't there, and it is time to retire this belief."

What if it turns out that pornography use actually reduces the desire to rape? It is a controversial idea, but some studies support it. Work in the 1960s and 1970s reported that sexual criminals tend to be exposed to pornographic materials at a later age than noncriminals. In 1992 Richard Green, a psychiatrist at Imperial College London, disclosed in his book *Sexual Science and the Law* that patients requesting treatment in clinics for sex offenders commonly say that pornography helps them keep their abnormal sexuality within the confines of their imagination. "Pornography seems to be protective," Diamond says, perhaps because exposure correlates with lower levels of sexual repression, a potential rape risk factor.

A Personal Concern

Repression seems to figure prominently into the puzzle of pornography. In 2009 Michael P. Twohig, a psychologist at Utah State University, asked 289 undergraduate students whether they considered their pornography consumption problematic; for example, causing intrusive sexual thoughts or difficulty finding like-minded sex partners. Then he assessed the students with an eye to understanding the root causes of their issues.

It turns out that among porn viewers, the amount of porn each subject consumed had nothing to do with his or her mental state. What mattered most, Twohig found, was whether the subjects tried to control their sexual thoughts and desires. The more they tried to clamp down on their urge for sex or porn, the more likely they were to consider their own pornography use a problem. The findings suggest that suppressing the desire to view pornography, for example, for moral or religious reasons, might actually strengthen the urge for it and exacerbate sexual problems. It's all about "personal views and personal values," Twohig says. In other words, the effects of pornography—positive or negative—have little to do with the medium itself and everything to do with the person viewing it. ■

MELINDA WENNER MOYER is a freelance science writer and frequent contributor to *Scientific American Mind*.

(Sex offenders say that pornography helps them keep their **abnormal sexuality** within the confines of their imagination.)

People who feel pornography is a problem in their lives are often those who try to suppress their sexual thoughts and desires.

(Further Reading)

- **Pornography, Public Acceptance and Sex Related Crime: A Review.** Milton Diamond in *International Journal of Law and Psychiatry*, Vol. 32, No. 5, pages 304–314; September/October 2009.
- **Viewing Internet Pornography: For Whom Is It Problematic, How, and Why?** Michael P. Twohig, Jesse M. Crosby and Jared M. Cox in *Sexual Addiction & Compulsivity*, Vol. 16, No. 4, pages 253–266; October 2009.

Does pornography harm women and relationships?

I am a senior family and individual psychotherapist. My long experience is that pornography is not at all harmful to anyone, even adolescents. I am a clinician, however, and not a scientist.

I do know that statistics establish correlations, not causes or effects. The correlations some cite about bad marriages and pornography do not establish anything causal. Spouses who are jealous of their partners' autoerotic private life need to grow up. A jealous partner who interprets the other's interest in porn as rejection might consider whether the other finds one an unsatisfactory partner in sex and life in general and get to work on making things better.

"Dr. Whom"
commenting at
www.ScientificAmerican.com/Mind

WARPED PERCEPTIONS

As a two-time All-American golfer for the University of Georgia, I can personally attest to the illusory perspective that the hole is larger on some days compared with others, as Andrea Anderson writes in "Towering Targets" [Head Lines].

That being said, my purpose for writing you has nothing to do with golf or any other sport but addresses the topic of perception itself as it relates to what people perceive to be true. Your article mentioned a general consensus that "what we see is often not an accurate reflection of the world around us."

Forget about the size of a baseball; if what you say is true about the inaccuracy of our perceptions, how can we be as sure as we are about the perception of our enemies—especially when you mix in some fear, anger and emotional sensitivity? Is our perception accurate enough to justify hurting or killing our enemies? Shouldn't we be more concerned about finding the truth behind our perceptions?

At this point in our evolution, I would hope that humankind could reach a general consensus on what is real. Unfortunately, that does not appear to be an accurate reflection of the world around us. I recommended this story to all of my friends and encouraged them to question the accuracy of their judgments. Great article!

Jeremy Parrott
Marietta, Ga.

REMEMBER THE BAD

"Lingering Lies," by Valerie Ross [Head Lines], reports that even when people understand, remember and believe a retraction, misinformation will still affect their inferences. Perhaps it should. After all, something makes lawyers reveal inadmissible evidence. Or, using the example in the study, there was probably a reason the original report said the bus passengers were elderly instead of a young hockey team. Without knowing why information was said to be wrong, can we really dismiss it? Perhaps the hockey team's coach was elderly, thus confusing the person who gave the first report. Remembering what was told us incorrectly might give us clues to a more complete picture.

"David N'Gog"
commenting at
www.ScientificAmerican.com/Mind

RELIEF FROM PANIC

Regarding Paul Li's answer about panic attacks in Ask the Brains, I would like to relate my own experience. Many years ago I started getting panic attacks. I couldn't drive over bridges or on freeways. I couldn't go to concerts or movies or be in enclosed spaces such as elevators. My attacks were just as Li described. I was debilitated for many years.

Then one day I heard on NPR about a young woman whose doctor put her on propranolol to keep her heart rate from rising. I realized that if I could keep my heart rate under control, maybe I could avoid panic attacks altogether. I called my doctor, and he said that this drug is used for stage fright. That is exactly how a panic attack feels.

I started taking propranolol, but it took three months before I got up the nerve to test its effect. I finally called a good friend, and we drove across every bridge in my city. I felt great and have never had another attack since. For me, propranolol is a miracle drug.

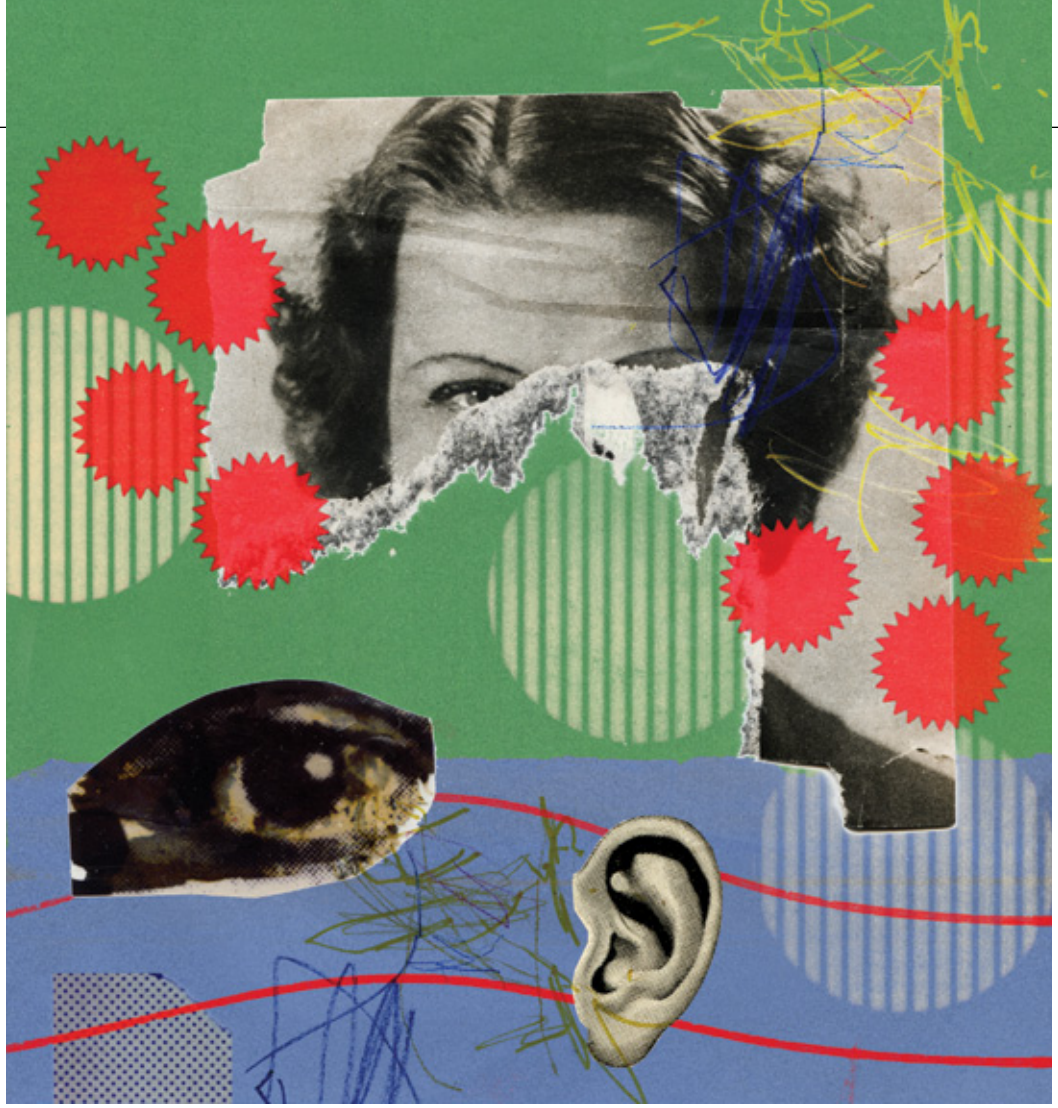
Susie Stanton
via e-mail

ERRATUM The order of the authors was incorrect in the byline of "Outsmarting Mortality" in the July/August 2011 issue. The correct order is Alexander Weiss, G. David Batty and Ian J. Deary.

HOW TO CONTACT US

For general inquiries or to send a letter to the editor:

Scientific American Mind
75 Varick Street, 9th Floor
New York, NY 10013
212-451-8200
editors@SciAmMind.com



MICHELLE THOMPSON

>> MOOD SWINGS

What Just Happened?

How unconscious cues affect our feelings

It happens to all of us: we suddenly and inexplicably feel cheery or blue, even though our mood was quite different just moments before. Often the culprit is a subliminal cue, or, as psychologists call it, priming. But we do not have to be at the mercy of these unconscious cues. Recent research suggests that simply recognizing the phenomenon can help us take control.

Researchers usually test the effects of priming by making participants believe they are taking part in a study of some other variable. In a University of Toronto study last year, people who were unconsciously exposed to images of fast-food logos became more impatient and less likely to be thrifty. In another study, published in the March issue of the *Journal of Psychosomatic Research,* when participants recalled an illness-related memory, their pain tolerance decreased.

A study from the October 2010 issue of *Social Cognition* revealed how nonconscious goals—those of which we are not aware—can put us in positive or negative "mystery moods."

A nonconscious goal might be one that has become so automatic you do not even realize you are still pursuing it, such as impressing the boss or taking fewer Facebook breaks. In the study some participants were unknowingly primed toward goal pursuit with a reading task that included words such as "success" and "achieve." When they failed at a subsequent puzzle, their mood was more negative than those who were not primed with goal-oriented words.

The key to outmaneuvering priming might simply be more self-awareness. Case in point: study participants' moods lifted when researchers pointed out why they had become blue. So if you suddenly find yourself in a funk, think about what you saw, heard and thought about in the past few minutes—sometimes simply identifying the trigger can help you move past it.

—Tori Rodriguez

>> MENTAL HEALTH

The Urban Brain

City living is linked with overactive emotional centers in the brain

GETTY IMAGES (*city*); TERRY WHITTAKER *Alamy* (*voles*)

In spite of the mind-expanding perks of city life, urban living is known to increase the chances of developing mental disorders such as schizophrenia. This link could be caused by a heightened response in the brain to social stress, according to a study published in *Nature* in June. Researchers at the University of Heidelberg in Germany studied brain scans of healthy students as they took a mathematics test under a barrage of disapproving feedback from the experimenter. This stressful situation revealed higher activity in the amygdala and anterior cingulate cortex—regions involved in regulating emotions and stress—in urban students as compared with rural ones, with small-town folk falling in between. The difference may reflect city dwellers' extra sensitivity to social stress, which could contribute to mental illness in people so predisposed by their genes. ***—Michele Solis***

>> DRUGS IN THE BRAIN

How Partners Prevent Addiction

Prairie voles in monogamous relationships respond less to drugs

Strong interpersonal relationships have been shown to ward off drug addiction, and new clues as to why come from prairie voles—rodents that form long-term, monogamous bonds with their mates. Kimberly A. Young of Florida State University and her colleagues found that pair-bonded voles responded less than unattached, sexually naive voles to the rewarding properties of amphetamine. The drug boosted dopamine, a brain chemical involved in pleasure and motivation, equivalently, but pair-bonded voles had fewer receptors ready to receive the dopamine signal. Such evidence that social attachments alter the brain's response to drugs may spur new ideas for addiction treatment. *—Michele Solis*

>> THE SENSES

Sniffing Out a Good Time

Ambient smells could make or break a party

Spotting a good dance party seems pretty easy: throbbing music, swaying bodies, flashing lights. But a new study, published in *Chemosensory Perception,* shows that partygoers should use their nose to find the best bash. Scientists found that ambient smells such as peppermint and orange increased clubbers' ratings of the dancing, the club, the music and the overall experience. The researchers say that smell is an important but previously underrated part of the multisensory party experience and that club owners—or hosts at home—could further impress their guests by adding scents to the surroundings. *—Carrie Arnold*

SIMON TONGE *Getty Images* (*dancing*)

FIONA McINTOSH *Getty Images*

>> MEMORY

Haunting Scenes

The most memorable photos may not be the ones you expect

Budding photographers, beware: the beauty of a serene sunset, a peaceful forest or a majestic mountain range is not sufficient to make a vacation snapshot memorable. In fact, pleasing images of landscapes or forests are often the hardest to recognize and remember later on, according to a study presented at the IEEE Conference on Computer Vision and Pattern Recognition in June.

Long thought to be too subjective to define, the properties that make a photo memorable actually remain largely constant from one person to the next, the study found. Researchers showed study participants hundreds of photos, some of which were repeated; pictures that the volunteers recognized as something they had seen before were considered the most memorable.

Using this method, researchers found that an attractive image is not more likely to be recognized. Rather "memorability seems more related to strangeness, funniness or interestingness," says Phillip Isola, a graduate student at the Massachusetts Institute of Technology and a lead researcher on the study.

Having people in the picture—even if they are strangers—also help make a photo more memorable, as does the implication of movement, such as a person running or waves crashing. Human-scale objects—chairs and cars rather than valleys and planets—similarly plant themselves in our mind. These observations support the evolutionary theory that our brain is wired to notice movement, other people and objects we can interact with, the researchers say, because these things would have been the most important features of the landscape we evolved in.

Still, scenes that lack these attributes are not doomed to be forgotten. Simple changes can increase their memorability, such as the presence of a tiny hiker in the background of a mountainous panorama. So the next time you're out to take a memorable shot, make it interesting—not just pretty.

—Allison Bond

>> MEDICAL TECHNOLOGY

Putting Insomnia on Ice

Cooling down our brains may help us sleep better

The pain and frustration of chronic insomnia affects one in 10 American adults, most of whom find no relief from current therapies. Now a new study finds that simply cooling the brain area just behind the forehead can help.

In a study presented this summer at the American Academy of Sleep Medicine's SLEEP 2011 conference, researchers fit 12 insomniacs with caps that use circulating water to cool the prefrontal cortex. The cap helps the insomniacs fall asleep about as fast—and stay asleep about as long—as adults without insomnia.

"When you get into the neurobiology, insomnia is a disorder of hyperarousal," says Eric A. Nofzinger, a psychiatrist at the University of Pittsburgh School of Medicine who worked on the study. In adults with normal sleeping patterns, the metabolism of the prefrontal cortex decreases as they fall asleep. In insomniacs, however, it increases—corresponding with the incessant worrying or brain chatter that many insomniacs report experiencing. Using the cap to perform a cooling process on the brain called cerebral hypothermia, the researchers were able to reduce the brain's activity and lull the subject to sleep.

The finding is significant because current treatments such as hypnosis and sleeping pills help only about one in four insomniacs. The cooling cap, which had a 75 percent success rate, may soon offer patients a safe, comfortable, nonpharmaceutical way to enjoy a good night's sleep. Participants reported that wearing the cap was a "soothing, massagelike experience," Nofzinger says. "Imagine your grandmother putting a cold washcloth on your forehead." He hopes that the cap may also prove useful to patients with anxiety and mood disorders, which also involve the prefrontal cortex. ***—Joe Kloc***

ISTOCKPHOTO (*brain*); MATTHIAS KULKA *Corbis (ice)*; GETTY IMAGES (*girl*)

>> PERSONALITY

I'm Not Sorry

Certain character traits influence people's willingness to apologize

After a fight and before forgiveness often comes an apology. But saying "I'm sorry" comes more easily for some people than it does for others. A new study suggests that specific personality traits offer clues about whether a person is likely to offer a mea culpa.

Psychologist Andrew Howell and his colleagues at Grant MacEwan University in Edmonton devised a questionnaire to measure a person's willingness to beg someone's pardon. They asked participants to indicate their level of agreement with a series of statements, such as "My continued anger often gets in the way of me apologizing" or "If I think no one will know what I have done, I am likely not to apologize." The researchers then used the answers to determine every participant's "proclivity to apologize," and they cross-referenced these scores with results from a variety of personality assessments.

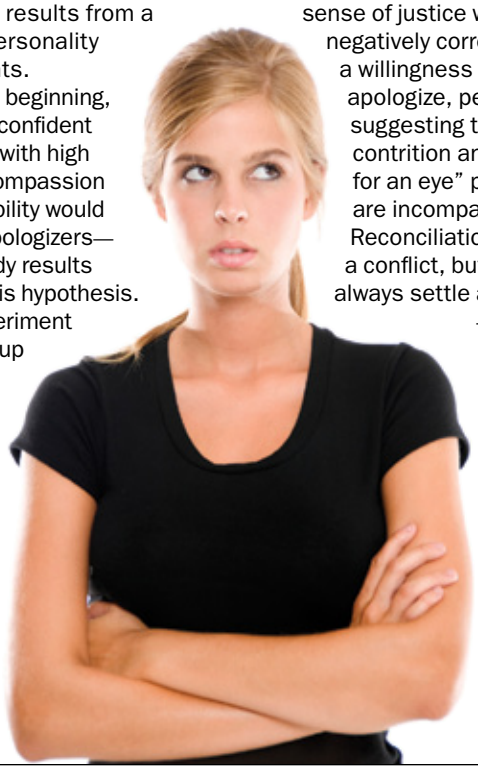
From the beginning, Howell was confident that people with high marks for compassion and agreeability would be willing apologizers—and the study results confirmed his hypothesis. But the experiment also turned up some surprising traits of the unrepentant.

People with low self-esteem, for example, were less inclined to apologize, even though they probably feel bad after a conflict. Unlike people who experience guilt about a specific action and feel sorry for the person they have wronged, individuals who experience generalized shame may actually be feeling sorry for themselves.

In contrast, "people who are sure of themselves have the capacity to confess to wrongdoing and address it," Howell suggests. But just the right amount of self-esteem is key. The study also found that narcissists—people who, in Howell's words, "are very egocentric, with an overly grand view of themselves"—were reluctant to offer an apology.

The researchers were most surprised to find that a strong sense of justice was negatively correlated with a willingness to apologize, perhaps suggesting that contrition and an "eye for an eye" philosophy are incompatible. Reconciliation may end a conflict, but it cannot always settle a score.

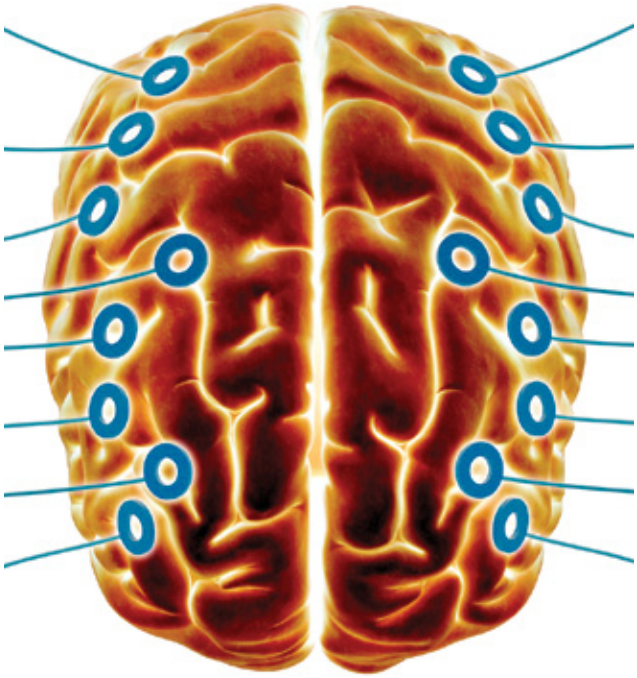
—Lauren F. Friedman



CONSCIOUSNESS

A Conversation in the Brain

Awareness requires a neural dialogue rather than any one key area



Scientists have long hunted for a pattern of brain activity that signals consciousness, but a reliable marker has proved elusive. For many years theorists have argued that the answer lies in the prefrontal cortex, a region of high-level processing located behind the forehead; neural signals that reach this area were thought to emerge from unconscious obscurity into our awareness. Recent research, however, supports the idea that consciousness is a conversation rather than a revelation, with no single brain structure leading the dialogue.

The most recent to challenge the prevailing theory is Simon van Gaal, a neuroscientist who investigates the borders of conscious awareness at the Neurospin Institute in Paris. He asks participants in his ongoing experiments to push a button every time they see a symbol flash on a screen, except when they see a certain icon that means "stop." During some of the trials van Gaal flashes the stop signal in a way that the subjects cannot consciously perceive. Although they do not see the stop signal, they hesitate to push the button, as though some part of the brain were choking on the information. As he runs the test, van Gaal measures brain activity with functional MRI and electroencephalography (EEG). He has found that the unconscious inhibitory signal seems to make it all the way up to parts of the prefrontal cortex.

The results indicate that "activity in a certain region is not sufficient to generate consciousness," van Gaal explains. Instead, he posits, different regions must exchange information before consciousness can arise.

A study in *Science* in May bolsters the claim that awareness emerges when information travels back and forth between brain areas rather than from ascending a linear chain of command. Researchers in Belgium recorded EEG signals in patients with brain damage as they listened to stimulating tones. All the patients were awake and alert, but with a range of responsiveness. Mathematical models built from the data suggest that feedback between the frontal cortex and the lower-level sensory areas is crucial to producing conscious experience. These results agree with previous work done with monkeys and healthy human volunteers.

Understanding consciousness has a universal philosophical appeal, but it is also clinically urgent, according to lead author Mélanie Boly of the University Hospital Center of Sart-Tilman in Liège, Belgium. "The diagnosis of patients in a vegetative state or minimally conscious state is extremely difficult, and the misdiagnosis rate can be as high as 40 percent," she says. By defining a neural correlate for consciousness, Boly and her colleagues hope to improve those patients' quality of care.

—Morgen E. Peck

GETTY IMAGES

GETTY IMAGES

UNCONSCIOUS AWARENESS

Something's Wrong with this Picture

Our subconscious notices incongruities in a scene

Ever do a double take without knowing why? Your unconscious mind may have noticed something that did not fit your expectations. A study published in June in *Psychological Science* suggests that the mind's unconscious awareness is capable of analyzing everyday situations for red flags and alerting our conscious brain about them. Psychologists at Tel Aviv University and the Hebrew University of Jerusalem showed subjects various scenes, masked by moving geometric shapes, which gradually became easier to see. Subjects were instructed to press a button as soon as they could make out the scene. They hit the button faster for incongruous situations—such as a basketball player dunking a watermelon—as compared with typical ones, which suggests that the unconscious mind was differentiating between them. [For more on this work and unconscious awareness, turn to the Consciousness Redux column, on page 20.]

—Melinda Wenner Moyer

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>> ANIMAL INTELLIGENCE

Clever Crustaceans

Crabs' memory systems are surprisingly complex

The *Chasmagnathus granulatus* crab leads a simple life. It spends its days burrowing for food and trying to avoid its nemesis, the seagull. But recent research has shown that despite its rudimentary brain, this crab has a highly sophisticated memory. For example, it can remember the location of a seagull attack and learn to avoid that area. In mammals, this kind of behavior requires multiple brain regions, but a study published in the June issue of the *Journal of Neuroscience* suggests that the *C. granulatus* crab can manage with just a few neurons.

Neuroscientists at the University of Buenos Aires used cardboard cutouts of seagulls to test crabs' memory skills. They found that the crabs could recognize the cardboard seagulls and figure out that they were nonthreatening—even when they appeared in different locations—implying an ability to apply learned knowledge. Moreover, the crabs retained this information: they still recognized the cutout 24 hours after the training session, the clinical benchmark for long-term memory in most animals, including humans.

The researchers tied the crabs' behavior to lobula giant neurons, a type of brain cell found in crustaceans. Electrical recordings showed that these cells become less active as the crabs get used to the cardboard seagulls. The researchers suspect that these neurons store information about stimuli, such as seagulls, and that another type of cell handles contextual details, such as the environment. "These animals don't have millions of neurons like mammals do, but they can still perform really complex tasks," says Julieta Sztarker, one of the study authors. If researchers can figure out how memory works in the most basic animals, Sztarker explains, they may have a better chance at understanding the much more complicated human system. —*Erica Westly*

Chasmagnathus granulatus

COURTESY OF MARTÍN BERÓN DE ASTRADA *Pavilion II, University City, Buenos Aires*

>> PERCEPTION

Better Safe Than Sorry

Our senses have difficulty parsing stimuli linked to a negative event

Performance usually improves with practice, but not if training is a rotten time. A new study shows that people's ability to identify noises declines when the sounds are paired with putrid smells—a phenomenon that may allow our brain to detect danger more quickly.

In a study published in May in *Nature Neuroscience*, neurobiologist Rony Paz of the Weizmann Institute of Science in Rehovot, Israel, and his colleagues exposed volunteers to auditory tones presented with no other stimuli or immediately followed by a rancid or fragrant odor delivered through a nose mask.

After this training session, the subjects were played a series of tone pairs—notes of very similar or identical frequencies—and asked whether the tones in each pair were the same or different. The subjects became better at distinguishing tones similar to those that had been presented alone or with a pleasant scent. But their ability to discriminate tones resembling those linked to a foul stench worsened—an effect that persisted one day later.

Such sensory confusion could be an adaptation that allows our defenses to rapidly mobilize. "This likely made sense in our evolutionary past," Paz says. "If you've previously heard the sound of a lion attacking, your survival might depend on a similar noise sounding the same to you." —*Janelle Weaver*

PETER CADE *Getty Images*

ELIJAS VAN ROON *Corbis (left)*; COURTESY OF ELISABETH PETRASCH-PARWEZ *Ruhr University Bochum (right)*

MENTAL ILLNESS

Motions Unmask Moods

Problems with motor control may be a key factor in bipolar disorder

None of us can stand perfectly still. No matter how hard we try, our bodies constantly make small adjustments, causing us to sway slightly as we stand. A new study finds that people with bipolar disorder tend to sway more than those who are unaffected, which may lead to new ways to treat and diagnose the illness.

When psychologists diagnose bipolar disorder, they typically look for mood swings between agitated mania and bleak depression. Previous studies have linked bipolar disorder to abnormalities in the cerebellum and basal ganglia, regions of the brain that are also important for motor control. This connection led Indiana University psychologist Amanda Bolbecker and her colleagues to hypothesize that people with bipolar disorder might also have problems with motor skills.

To test their idea, Bolbecker's team had 16 people with bipolar disorder and 16 age-matched healthy control subjects stand on a device called a force platform. The platform is similar in appearance to a bathroom scale, but instead of measuring weight it calculates the pressure from different parts of the feet, which indicates how the body is swaying.

In every trial—with their eyes open or closed and with their feet different widths apart—the people with bipolar disorder wobbled more than the healthy subjects, indicating problems with motor control. The patients had the most trouble with their eyes closed, which suggests that the bipolar brain has difficulty integrating sensorimotor information, those inputs from the body and senses that assist the brain in maintaining balance and body position.

Bolbecker points out that the cerebellum, located at the base of the brain, helps to regulate movement and is also involved in emotional reactions, such as fear and pleasure. In addition, the cerebellum connects to other parts of the brain linked to cognition, mood regulation and impulse control, three areas in which patients with bipolar disorder often have difficulties. If the cerebellum is damaged at the cellular level, it may create problems with both mood and motor control. *—Carrie Arnold*

PATHOLOGY

Suicide Cells

People who kill themselves have more of a type of neuron important for social emotions

A certain type of brain cell may be linked with suicide, according to a recent investigation. People who take their own lives have more densely packed von Economo neurons, large spindle-shaped cells that have dramatically increased in density over the course of human evolution.

Researchers in Germany analyzed the roots of suicide in the brain by focusing on a neural network linked with psychological pain, which includes regions such as the anterior cingulate cortex and the anterior insula, where von Economo neurons are concentrated. These cells bear receptors for neurotransmitters that help to regulate emotion, such as dopamine, serotonin and vasopressin. Because they are found in highly gregarious animals such as whales, elephants and apes—with humans possessing the highest densities—scientists believe they might specifically deal with complex social emotions such as shame.

von Economo neurons

The team compared the density of von Economo neurons in nine patients who died from suicide and 30 who died of natural causes, such as heart failure. All subjects had been diagnosed clinically with either schizophrenia or bipolar disorder. The researchers found the density of these neurons was significantly greater in those who died of suicide than in those who had not, regardless of what disorder they had. Evolutionary psychiatrist and neuroscientist Martin Brüne of University Hospital Bochum and his colleagues detailed these findings online June 22 in *PLoS ONE*.

If von Economo neurons do play a role in processing complex emotions such as empathy, guilt and shame, an overabundance may in some cases trigger emotional disturbances, potentially explaining the link seen with suicidal behavior, Brüne says. He adds that high densities of von Economo neurons do not necessarily cause suicide: "Having good empathetic abilities is certainly something that is advantageous in most situations but perhaps can have deleterious effects under very specific circumstances." Future insights into the role of these cells in emotion and cognition might lead to ways of addressing suicidal tendencies, he says. *—Charles Q. Choi*

>> SOCIAL COGNITION

Gossip Shapes What We See

Having a bad reputation gets you noticed

Gossip can act as a useful social shortcut—it lets you know whom to avoid without your having to learn a person's faults the hard way. And gossip may also influence whether you notice someone in the first place, according to a study published in *Science* on June 17.

To test whether gossip affects visual awareness, psychologist Lisa Feldman Barrett of Northeastern University and her collaborators took advantage of a phenomenon called binocular rivalry. Each eye is presented with a different image, and the viewer consciously perceives them as alternating back and forth. The alternation between images is not under the subject's control, and it typically happens every few seconds.

In the study, 66 volunteers first saw pictures of 30 faces, each paired with a sentence describing a negative, positive or neutral social behavior. For example, a face could be associated with the act of throwing a chair at a classmate, helping an elderly woman with her groceries or passing a man on the street.

After learning these relationships, the subjects were shown faces in one eye and houses in the other, and they pressed buttons to indicate which one they were seeing. Judging by the length

of their button presses, the subjects spent more time perceiving the faces linked to negative actions than the visages connected to positive or neutral acts. This preference for seeing bad people could be protective, the authors suggest, because it might allow us to monitor threatening behavior from afar. *—Janelle Weaver*

>> MEDITATION

Therapy in the Air

Focused attention on breathing can boost mood

Feeling tense? Paying attention to your breathing for a few minutes could soothe your nerves. Practicing such mindful breathing regularly may even lead to better mental health, according to two recent studies.

In an experiment reported in May in the *International Journal of Psychophysiology,* researchers at Toho University School of Medicine in Japan taught healthy subjects to breathe deeply into their abdomen. After subjects maintained attention on breathing this way for 20 minutes, they had fewer negative feelings, more of the mood-boosting neurotransmitter serotonin in their blood, and more oxygenated hemoglobin in the prefrontal cortex, an area associated with attention and high-level processing.

Another study, in the April issue of *Cognitive Therapy and Research,* looked at depression symptoms. Investigators at Ruhr University Bochum in Germany asked healthy participants to stay in mindful contact with their breathing—maintaining continual awareness without letting their mind wander. During the 18-minute trials researchers asked the subjects frequently whether they were succeeding in doing so. Those who were able to sustain mindful contact with their breathing reported less negative thinking, less rumination and fewer of the other symptoms of depression.

"In my opinion, the cultivation of mindfulness through breathing meditation helps to prevent depression," says study author Jan M. Burg, although he cautions that this interpretation goes beyond the findings of his research. Mindfulness, Burg explains, may allow people to disengage from dysfunctional rumination, a central risk factor for depression.

Anyone can try a bit of this technique on the fly. Simply sit up comfortably and breathe naturally. Focus your attention on your breath, feeling it in detail—in the nasal cavity, the chest and the abdomen. If you notice your mind wandering, try to redirect your attention to your breathing—it is important, Burg says, not to criticize yourself during this process. At first it might be difficult to stay focused, but with some practice you should be able to hit the mark these studies showed to be beneficial, about 20 minutes. And once you have the hang of it, even a few minutes of mindful breathing can help you become more calm and collected before a high-stakes meeting or any other stressful situation. *—Tori Rodriguez*

GETTY IMAGES (*top*); CORBIS (*bottom*)

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Is Free Will an Illusion?

Don't trust your instincts about free will or consciousness, experimental philosophers say

BY SHAUN NICHOLS

IT SEEMS OBVIOUS to me that I have free will. When I have just made a decision, say, to go to a concert, I feel that I could have chosen to do something else. Yet many philosophers say this instinct is wrong. According to their view, free will is a figment of our imagination. No one has it or ever will. Rather our choices are either determined—necessary outcomes of the events that have happened in the past—or they are random.

Our intuitions about free will, however, challenge this nihilistic view. We could, of course, simply dismiss our intuitions as wrong. But psychology suggests that doing so would be premature: our hunches often track the truth pretty well [see "The Powers and Perils of Intuition," by David G. Myers; Scientific American Mind, June/July 2007]. For example, if you do not know the answer to a question on a test, your first guess is more likely to be right. In both philosophy and science, we may feel there is something fishy about an argument or an experiment before we can identify exactly what the problem is.

The debate over free will is one example in which our intuitions conflict with scientific and philosophical arguments. Something similar holds for intuitions about consciousness, morality, and a host of other existential concerns. Typically philosophers deal with these issues through careful thought and discourse with other theorists. In the past decade, however, a small group of philosophers have adopted more data-driven methods to illuminate some of these confounding questions. These so-called experimental philosophers administer surveys, measure reaction times and image brains to understand the sources of our instincts. If we can figure out why we feel we have free will, for example, or why we think that consciousness consists of something more than patterns of neural activity in our brain, we might know whether to give credence to those feelings. That is, if we can show that our intuitions about free will emerge from an untrustworthy process, we may decide not to trust those beliefs.

Unknown Influences

To discover the psychological basis for philosophical problems, experimental philosophers often survey people about their views on charged issues. For instance, scholars have argued about

(perspectives)

Is Free Will an Illusion?

Don't trust your instincts about free will or consciousness, experimental philosophers say

BY SHAUN NICHOLS

DAVID SENIOR

Robots can produce the impression that they have feelings, but they are not **plausible candidates** for possessing awareness.

whether individuals actually believe that their choices are independent of the past and the laws of nature. Experimental philosophers have tried to resolve the debate by asking study participants whether they agree with descriptions such as the following:

> *Imagine a universe in which everything that happens is completely caused by whatever happened before it. So what happened in the beginning of the universe caused what happened next and so on, right up to the present. If John decided to have french fries at lunch one day, this decision, like all others, was caused by what happened before it.*

When surveyed, Americans say they disagree with such descriptions of the universe. From inquiries in other countries, researchers have found that Chinese, Colombians and Indians share this opinion: individual choice is not determined. Why do humans hold this view? One promising explanation is that we presume that we can generally sense all the influences on our decision making—and because we cannot detect deterministic influences, we discount them.

Of course, people do not believe they have conscious access to everything in their mind. We do not presume to intuit the causes of headaches, memory formation or visual processing. But research indicates that people do think they can access the factors affecting their choices.

Yet psychologists widely agree that unconscious processes exert a powerful influence over our choices. In one study, for example, participants solved word puzzles in which the words were either associated with rudeness or politeness. Those exposed to rudeness words were much more likely to interrupt the experimenter in a subsequent part of the task. When debriefed, none of the subjects showed any awareness that the word puzzles had affected their behavior. That scenario is just one of many in which our decisions are directed by forces lurking beneath our awareness.

Thus, ironically, because our subconscious is so powerful in other ways, we cannot truly trust it when considering our notion of free will. We still do not know conclusively that our choices are determined. Our intuition, however, provides no good reason to think that they are not. If our instinct cannot support the idea of free will, then we lose our main rationale for resisting the claim that free will is an illusion.

Is Consciousness Just a Brain Process?

Though a young movement, experimental philosophy is broad in scope. Its proponents apply their methods to varied philosophical problems, including questions about the nature of the self. For example, what (if anything) makes you the same person from childhood to adulthood? They investigate issues in ethics, too: Do people think that morality is objective, as is mathematics, and if so, why? Akin to the question of free will, they are also tackling the dissonance between our intuitions and scientific theories of consciousness.

Scientists have postulated that consciousness is populations of neurons firing in certain brain areas, no more and no less. To most people, however, it seems bizarre to think that the distinctive tang of kumquats, say, is just a pattern of neural activation.

Our instincts about consciousness are triggered by specific cues, experimental philosophers explain, among them the existence of eyes and the appearance of goal-directed behavior, but not neurons. Studies indicate that people's intuitions tell them that insects—which, of course, have eyes and show goal-directed behavior—can feel happiness, pain and anger.

The problem is that insects very likely lack the neural wherewithal for these sensations and emotions. What is more, engineers have programmed robots to display simple goal-directed behaviors, and these robots can produce the uncanny impression that they have feelings, even though the machines are not remotely plausible candidates for having awareness. In short, our instincts can lead us astray on this matter, too. Maybe consciousness does not have to be something different from—or above and beyond—brain processes.

Philosophical conflicts over such concepts as free will and consciousness often have their roots in ordinary intuitions, and the historical debates often end in stalemates. Experimental philosophers maintain that we can move past some of these impasses if we understand the nature of our gut feelings. This nascent field will probably not produce a silver bullet to fully restore or discredit our beliefs in free will and other potential illusions. But by understanding why we find certain philosophical views intuitively compelling, we might find ourselves in a position to recognize that, in some cases, we have little reason to hold onto our hunches. M

SHAUN NICHOLS is a philosopher and cognitive scientist at the University of Arizona, where he directs the Experimental Philosophy Laboratory.

(Further Reading)

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Probing the Unconscious Mind

Cognitive psychology is mapping the capabilities we are unaware we possess

BY CHRISTOF KOCH

SIGMUND FREUD popularized the idea of the unconscious, a sector of the mind that harbors thoughts and memories actively removed from conscious deliberation. Because this aspect of mind is, by definition, not accessible to introspection, it has proved difficult to investigate. Today the domain of the unconscious—described more generally in the realm of cognitive neuroscience as any processing that does not give rise to conscious awareness—is routinely studied in hundreds of laboratories using objective psychophysical techniques amenable to statistical analysis. Let me tell you about two experiments that reveal some of the capabilities of the unconscious mind. Both depend on "masking," as it is called in the jargon, or hiding things from view. Subjects look but don't see.

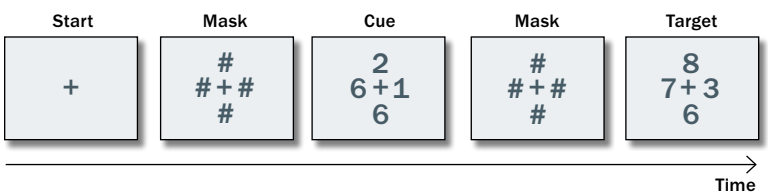
Unconscious Arithmetic

The first experiment is a collaboration among Filip Van Opstal of Ghent University in Belgium, Floris P. de Lange of Radboud University Nijmegen in the Netherlands and Stanislas Dehaene of the Collège de France in Paris. Dehaene, director of the INSERM-CEA Cognitive Neuroimaging Unit, is best known for his investigations of the brain mechanisms underlying counting and numbers. Here he explored the extent to which a simple sum or an average can be computed outside the pale of consciousness. Adding 7, 3, 5 and 8 is widely assumed to be a quintessential serial process that requires consciousness. Van Opstal and his colleagues proved the opposite in an indirect but clever and powerful way.

A quartet of single-digit Arabic numbers (1 through 9, excluding the numeral 5) are projected onto a screen. Volunteers had to indicate as quickly as possible whether or not the average of the four projected numbers exceeded 5. Every trial was preceded by a hidden cue that could be valid or invalid. The cue consisted of a very brief flash of another set of four numbers whose average was either smaller or larger than 5 [*see illustration below*]. These were preceded and followed by hash marks at the location of the flashed numbers. The marks effectively masked the cue so that no subject ever consciously saw this quartet. Forcing them to guess whether the average of the four hidden numbers was less than or greater than 5 did not work either: they were at chance.

Yet the cue still influenced the subject's reaction to the main response. If the implicit cue was valid, the response to the target was consistently faster than if the cue was invalid. In the illustration, the mean of the four invisible cues (3.75) is less than 5, whereas the average of the visible target numbers is greater than 5. Resolving this conflict demands additional processing time (about 1/40 of a second). That is, the cue triggers neural activity representing the assertion "less than 5," which interferes with the rapid establishment of a coalition of neurons represent-

In the experiment, subjects saw four numbers for 600 milliseconds and had to judge quickly whether their average exceeded 5. Masks with hash marks ensured that the four cued numbers were not consciously seen. The unconscious was nonetheless able to estimate the average.



CHRISTOF KOCH (*Koch*); YULIA_M Getty Images (*woman in clothes hanger*)

The ability to rapidly integrate **disparate elements** in a scene and place them in context is a hallmark of consciousness.

ing "greater than 5." That invisible and undetectable cues influence behavior implies that the unconscious can somehow estimate the average of four single digits. It is unlikely that it does so following the precise, algebraic rules children learn in grade school. Instead it may rely on heuristics: for example, for each number larger than 5, increase the probability of pushing the greater than 5 button.

This is just the latest in a flurry of experiments demonstrating so-called ensemble coding, the ability of the mind to guesstimate the dominant emotional expression of a crowd of faces or the approximate size of a bunch of dots even though the individual faces or dots are not consciously perceived.

What's Wrong with this Picture?

Liad Mudrik and Dominique Lamy of Tel Aviv University and Assaf Breska and Leon Y. Deouell of the Hebrew University in Jerusalem set out to test the extent to which the unconscious can integrate all the information in any one picture into a unified and coherent visual experience. Giulio Tononi and I had proposed in the last Consciousness Redux column [September/October 2011] that the ability to rapidly integrate all the disparate elements within a scene and place them into context is one of the hallmarks of consciousness.

The Israeli researchers used "continuous flash suppression," a powerful masking technique, to render images invisible. A series of rapidly changing, randomly colored patterns was flashed into one eye while a photograph of a person carrying out some task was slowly faded into the other eye. For a few seconds, the picture is completely invisible, and the subject can see only the colored shapes. Because the images become progressively stronger, eventually they will break through, and the subject will see them. It is like Harry Potter's cloak of invisibility fading with time and revealing what is underneath.

The unconscious mind can tell if there is something amiss in these doctored images.

The fascinating aspect of the Mudrik study is that the time to become visible depends on the content of the image. Realistic scenes that depict a woman placing a pizza into an oven, a boy taking aim with a bow and arrow, or a basketball player dunking a ball into a hoop took 2.64 seconds to become visible, whereas unnatural scenes were masked for only 2.50 seconds, a small but significant difference. That is, the unconscious mind detected something incongruent about these pictures: a woman puts a chessboard into the oven, the cocked arrow is replaced by a tennis racket, and the basketball becomes a watermelon. The psychologists made sure that both congruent and incongruent images were truly invisible and could not be distinguished from one another when masked in this way. This discovery implies that the unconscious can recognize something is amiss in these images, that the object handled by the person in the image is not appropriate to the context.

How the mind recognizes that something is wrong is puzzling. Maybe because the vast and tangled neural networks of the cerebral cortex that encode images have learned that certain objects go together but others do not (akin to the software programs—bots—that Google and other search engines employ to trawl the Internet to list all images, sentences and Web pages so when you search for them they are readily accessible). Given the sheer infinite number of possible pairings of objects and context, is this solution likely to be done by the brain? Or maybe the masking techniques suppress visibility of the image but do not fully eliminate conscious access to them? Only more research will tell. In this way, we shall ultimately know the capabilities of the cognitive unconscious and the truly essential function that consciousness plays in our life. M

CHRISTOF KOCH is Lois and Victor Troendle Professor of Cognitive and Behavioral Biology at the California Institute of Technology and chief scientific officer at the Allen institute for Brain Science in Seattle. He serves on *Scientific American Mind*'s board of advisers.

(Further Reading)

- **Integration without Awareness: Expanding the Limits of Unconscious Processing.** Liad Mudrik, Assaf Breska, Dominique Lamy and Leon Y. Deouell in *Psychological Science,* Vol. 22, No. 6, pages 764–770; June 2011.
- **Rapid Parallel Semantic Processing of Numbers without Awareness.** Filip Van Opstal, Floris P. de Lange and Stanislas Dehaene in *Cognition,* Vol. 120, No. 1, pages 136–147; July 2011.

COURTESY OF LIAD MUDRIK *Tel Aviv University*

Sculpting the Impossible: Solid Renditions of Visual Illusions

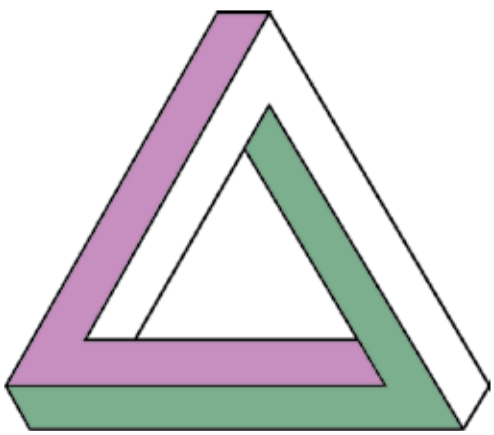
Artists find mind-bending ways to bring impossible figures into three-dimensional reality

BY STEPHEN L. MACKNIK AND SUSANA MARTINEZ-CONDE

IN AN IMPOSSIBLE FIGURE, seemingly real objects—or parts of objects—form geometric relations that physically cannot happen. Dutch artist M. C. Escher, for instance, depicted reversible staircases and perpetually flowing streams. Mathematical physicist Roger Penrose drew his famously impossible triangle, and visual scientist Dejan Todorović of the University of Belgrade in Serbia created a golden arch that won him third prize in the 2005 Best Illusion of the Year Contest. These effects challenge our hard-earned perception that the world around us follows certain, inviolable rules. They also reveal that our brains construct the feeling of a *global* percept—an overall picture of a particular item—by sewing together multiple *local* percepts. As long as the local relation between surfaces and objects follows the rules of nature, our brains don't seem to mind that the global percept is impossible.

Several contemporary sculptors recently have taken up the challenge of creating impossible art. That is, they are interested in shaping real-world 3-D objects that nonetheless appear to be impossible. Unlike classic monuments—such as the Lincoln Memorial in Washington, D.C.—which can be perceived by either sight or touch, impossible sculptures can be interpreted (or *misinterpreted*, as the case may be) only by the visual mind.

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



PENROSE TRIANGLE

The impossible triangle (also called the Penrose triangle or the tribar) was first created in 1934 by Oscar Reutersvärd. Penrose attended a lecture by Escher in 1954 and was inspired to rediscover the impossible triangle. Penrose (who at the time was unfamiliar with the work of Reutersvärd, Giovanni Piranesi and other previous discoverers of the impossible triangle) drew the illusion in its now most familiar form (*above*) and published his observations in the *British Journal of Psychology* in 1958, in an article co-authored with his father, Lionel. In 1961 the Penroses sent a copy of the article to Escher, who incorporated the effect into *Waterfall,* one of his most famous lithographs (*right*).

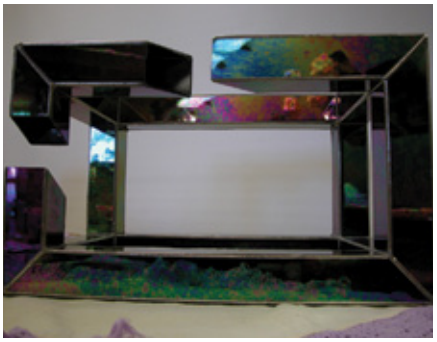
IMPOSSIBLE ARCH

Elusive Arch, by Todorović, shows a new impossible figure. The left-hand part of the figure appears as three shiny oval tubes. The right-hand part looks corrugated, with three alternating pairs of shallow matte ridges and grooves. The bright streaks on the figure's surface are seen either as highlights at the peaks and troughs of the tubes or as inflections between grooves. Determining the direction of the apparent illumination falling on the figure is difficult: it depends on whether we interpret the light as falling on a receding or an expanding surface. Further, determining the exact position and shape of the transition region near the center of the arch is maddening, because the local 3-D interpretations defy the laws of illumination. For more about the arch, see http://illusioncontest.neuralcorrelate.com/2005/elusive-arch.

HOMAGE TO ESCHER

Escher's *Belvedere* (*left*) showcases columns that switch walls between their bases and capitals, a straight ladder whose base rests inside the building yet nonetheless enters the building from the outside at its top, and a sitting man holding an impossible cube. Mathieu Hamaekers, a Belgian mathematician and sculptor, created an homage to *Belvedere* that features a real-life impossible cube. This photograph (*below*) shows the artist holding the sculpture *Upside Down,* built in 1985.





IMPOSSIBLE BOX

Hans Schepker has built outstanding sculptures of impossible objects, such as this *Crazy Crate* made from glass (*above left*). Other views of the crazy crate show the method behind the madness (*above center* and *right*). Notice that the illusion works only from a specific vantage point. At any other angle, the illusion fails. Scientists refer to this as the accidental view, but there is nothing accidental about it. To perceive the illusion, the view must be carefully staged and choreographed, or else the audience will fail to see the "impossible" sculpture.

AND THE WINNER IS ...

For several years, Italian sculptor Guido Moretti has donated copies of his *Three-Bar Cube* and other impossible sculptures as trophies for the Best Illusion of the Year Contest. Depending on your vantage point, *Three-Bar Cube* can appear to be a cube, a solid structure or an impossible triangle. For more information, see http://illusioncontest.neuralcorrelate.com/trophies.



INDUSTRIAL-SIZE TRIANGLE

Artist Brian McKay created a giant version of the impossible triangle (*below left*) in Perth, Australia, in collaboration with architect Ahmad Abas. How did they do that? A photograph taken from another angle (*below right*) reveals the trick.

COURTESY OF HANS SCHEPKER (*glass boxes*); COURTESY OF GUIDO MORETTI (WWW.GUIDOMORETTI.IT) (*cube sculptures*); COURTESY OF BJØRN CHRISTIAN TØRRISSEN (BJORNFREE.COM) (*triangles*)

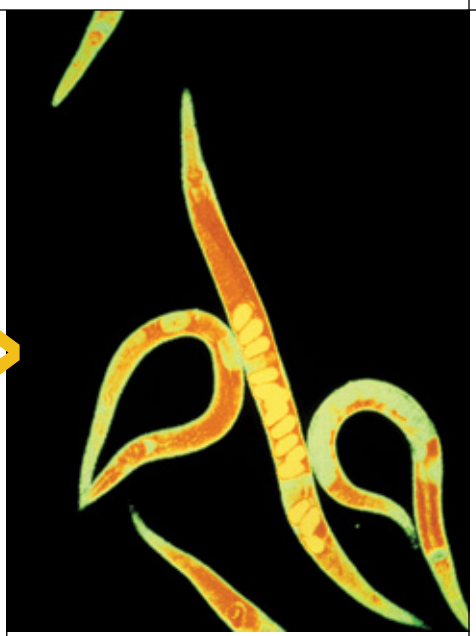
(calendar)

November

4–5 According to the World Health Organization, one in four of us will develop at least one mental illness or behavioral disorder in our lifetime. Depression alone affects an estimated 121 million people worldwide. At the two-day **EMBO/EMBL Science and Society Conference**, biologists, psychologists and neuroscientists will explore the ethical and social implications of major mental illnesses as well as their causes and treatment. Attendees will debate the definitions of mental disorders, financial interests in the refinement of both diagnoses and drugs, and controversial new therapies, among other topics.
Heidelberg, Germany
www.embo.org

UNTIL 5 Little-known fact: brain tumors kill approximately 13,000 people every year in the U.S. Although advances in treatments have reduced the progression of tumors and extended patients' lifetime, new therapies are needed. During the fifth **International Brain Tumor Awareness Week**, supporters and survivors will organize activities to help raise awareness of this devastating disease, its causes and potential treatments. Past activities have included a charity walk, a picnic and a scientific conference.
Walks take place in several locations around the world
www.theibta.org

12–16 Which elements of human behavior are dictated by genes, and which are influenced by experience? *C. elegans*, the soil-dwelling worm that has achieved notoriety as a model organism in science, is helping researchers discover the answer. At the five-day **Society for Neuroscience Conference**, Cornelia I. Bargmann of the Rockefeller University will discuss her team's findings on the behavior of worms, including a gene that determines whether they prefer to eat alone or in groups. Her lab has also found a molecule that guides neurons to form connections during worms' early development, potentially hinting at how human brains develop, too.
Washington, D.C.
www.sfn.org/AM2011



C. elegans

SIMON FRASER *Photo Researchers, Inc.* (*brain scan*); JAMES KING-HOLMES *Photo Researchers, Inc.* (*C. elegans*); ISTOCKPHOTO (*microphone*)

LECTURE SERIES ROUNDUP **Talks on the Brain**

November 2

You may recall the compelling story of Jill Bolte Taylor, the Harvard-trained neuroanatomist who suffered a severe stroke in the left hemisphere of her brain in 1996 and made a stunning recovery eight years later. As part of **INSIGHT Lectures**, Taylor will talk about the research she conducted before her stroke and the details of her disorder and recovery. Notably, she will discuss the differences between the right and left sides of the brain, tactics to minimize the effects of a stroke, and the experience of being both a patient and a doctor.
Seattle
www.insightlecture.com/speakers/jill-bolte-taylor-ph-d

November 11–12

Empathy is a fundamental aspect of human social interactions. Recent evidence suggests we possess specific neural circuitry dedicated to experiencing the pain of others. A two-day symposium, **Empathy: Self, Society, Culture**, hosted by Indiana University, will delve into the biological and cultural roots of this trait. Attendees will discuss why empathy exists, advances in understanding the neural basis of altruism, and the ways in which society affects our empathetic tendencies.
Bloomington, Ind.
http://poynter.indiana.edu/empathy.shtml

December 5–11

Our brains continue to form new neural pathways and rewire old ones throughout our lives. At the weeklong **International Psychology of Health, Immunity and Disease Conference**, neuroscientists and psychologists will explore the brain's malleability and how this trait can be exploited to help people reduce stress and heal trauma. Conference attendees will also delve into the potential benefits of energy psychology, which includes the alternative therapies of acupuncture and hypnosis, to treat patients with post-traumatic stress disorder, anxiety and addiction problems.
Hilton Head Island, S.C.
www.nicabm.com/december-conference/save-the-date

December 8

Although mindfulness originated as a component of Buddhist tradition, the practice is fast gaining popularity in the U.S. and Europe as an alternative to pharmaceutical therapies in relieving the burden of anxiety disorders, depression and other conditions. In his lecture entitled **The Psychology of Meditative Thinking**, James Mitchell, an instructor at University of California, San Francisco, will explain how mindfulness meditation can improve overall health, reduce stress levels and create a calmer state of mind.
San Francisco
www.osher.ucsf.edu/public/lunchtime.html

Compiled by Victoria Stern. Send items to editors@SciAmMind.com

ANSWERS IN YOUR DREAMS

When you fall asleep, you enter an alternative state of consciousness—a time when true inspiration can strike

By Deirdre Barrett

As a young mathematician in the 1950s, Don Newman taught at the Massachusetts Institute of Technology alongside rising star and Nobel-laureate-to-be John Nash. Newman had been struggling to solve a particular math problem: "I was … trying to get somewhere with it, and I couldn't and I couldn't and I couldn't," he recalled.

One night Newman dreamed that he was reflecting on the problem when Nash appeared. The sleeping Newman related the details of the conundrum to Nash and asked if he knew the solution. Nash explained how to solve it. Newman awoke realizing *he had the answer!* He spent the next several weeks turning the insight into a formal paper, which was then published in a mathematics journal.

PHOTOILLUSTRATION BY AARON GOODMAN

Newman is hardly alone in making a practical breakthrough during a night of sleep. While dreaming, Friedrich August Kekulé came up with the structure of benzene, Dmitry Mendeleyev conjured up his final form of the periodic table of the elements and Otto Loewi thought of the neuroscience experiment that won him a Nobel Prize in medicine. Modern engineers Paul Horowitz and Alan Huang dreamed designs for laser-telescope controls and laser computing, respectively. Innumerable artists and filmmakers have depicted images that came to them in their sleep. Mary Shelley dreamed the two main scenes that became *Frankenstein,* and Robert Louis Stevenson did the same with *Dr. Jekyll and Mr. Hyde*. Ludwig van Beethoven, Paul McCartney and Billy Joel all awoke to discover new tunes ringing in their minds. Mahatma Gandhi's call for a nonviolent protest of British rule of India was inspired by a dream.

Yet dreams so often seem incoherent, bizarre or even trivial. We search intensely for our brother in an endless maze of corridors because we *must* give him a yellow package. But when we find him, we have forgotten the package—which we are certainly not holding any longer—and anyway he is now a neighbor, not a brother. Other dreams are ephemeral—we wake up thinking about a yellow box, but that is all we recall.

Dreams are simply thought in a different biochemical state. We continue focusing on all the same issues that concern us while we are awake.

For decades scientists have puzzled over how dreams could display such diverse characteristics. Research is beginning to suggest that dreams are simply thought in a different biochemical state. The physiological demands of sleep alter the way the brain functions. Dreams may seem bizarre or nonsensical because the chemistry of the sleeping brain affects how we perceive our own thoughts, but we nonetheless continue focusing on all the same issues that concern us while we are awake. This unusual state of consciousness is often a blessing for problem solving—it helps us find solutions outside our normal patterns of thought. By following a few simple steps, we can even harness this power, encouraging our sleeping brain to ruminate on particular concerns.

FAST FACTS

Solutions in Sleep

1» The act of dreaming is simply thinking about our usual concerns in a different state of consciousness.

2» Dreams can be especially helpful for problems that require creativity or visualization to solve.

3» By thinking about specific dilemmas before bed, we can increase our chances that we will dream a solution.

Anatomy of a Dream

One often hears the question, "What is dreaming for?" You would never pose such a simplistic query about waking thought. It is for *everything.*

Nevertheless, theorists have long offered one-function explanations for dreaming. Sigmund Freud believed that dreams primarily express repressed wishes, namely, infantile sexual and aggressive impulses. Other psychoanalysts thought they had more to do with narcissistic strivings or compensation for feelings of inferiority. More recently, psychologists have posited that dreams simulate threats or help to consolidate memories. All these theories characterize some dreams, but none of them can account for every type. Just as waking thought can drift between reminiscing, planning, rumination, and so on, dream cognition seems to encompass many modes of thought.

Most early theorists assumed that the dreams we remembered constituted *all* dreams. Several hypotheses supposed that people experienced dreams when some specific situation triggered a set of distinctive feelings—the desire for sex, say, or a bruised ego. In the 1950s, however, a series of groundbreaking studies by Eugene Aserinsky and Nathaniel Klietman, both then at the University of Chicago, revealed that people have many

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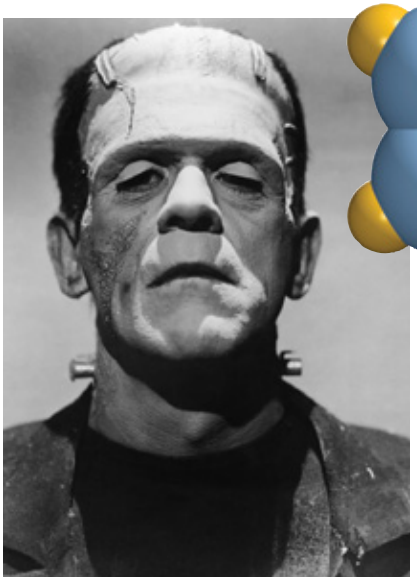
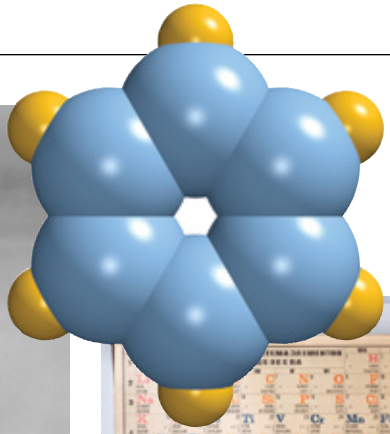
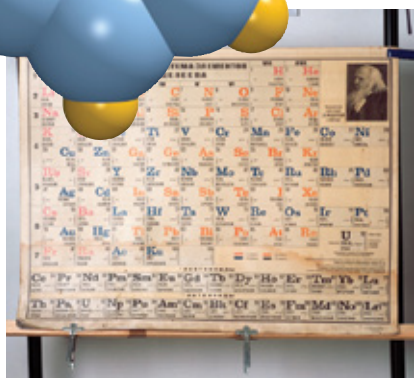






Many revolutionary ideas and works of art have grown from a dream, including Mary Shelley's *Frankenstein,* Friedrich August Kekulé's discovery of the structure of benzene, Dmitry Mendeleyev's layout of the periodic table of the elements, and architect Solange Fabião's design for the Museum of Ocean and Surf in Biarritz, France, built this past year.

more dreams than they are likely to remember. The two sleep researchers discovered that human slumber consists of approximately 90-minute cycles, each one containing a period of rapid eye movement (REM) and heightened brain activity—about as much activity as when we are awake. When the scientists awakened people near the end of each REM period, the sleepers recounted an average of almost five dreams per night. The discrepancy between the subjects' reports when awakened right after the REM period, as opposed to later, led the scientists to conclude that dreams almost always accompany this stage of sleep even if none are recalled by morning.

Within the past two decades positron-emission tomography (PET) scans have allowed us to see which brain areas are involved in dreaming. Parts of the cortex associated with visual imagery and the perception of movement become activated even more dramatically than when we are awake, as do some deep brain areas associated with emotion. In contrast, the dorsolateral prefrontal cortex is less engaged during dreaming; this area is associated with volitional action and the evaluation of what is logical and socially appropriate. These PET results fit the characteristics of dreams well; dream reports almost always contain visual imagery and often involve movement. The prefrontal findings fit neatly with the fact that dreams have long been associated with less "censorship"—not only in the Freudian sense of uninhibited sex and aggression but also in terms of filtering out scenarios that are illogical or abnormal. We will return to this point when discussing problem solving. Sometimes tackling a puzzle the "wrong" way can lead to surprising insights.

Evolutionary psychologists were quick to point out that this PET portrait of the dreaming brain makes sense because such activity would have supported human survival—certain areas of the brain are safer to turn on and off during sleep than others. Donald Symons, an anthropologist at the University of California, Santa Barbara, argued in his 1993 paper "The Stuff That Dreams Aren't Made Of" that sleepers must monitor the environment with specific senses—to smell smoke, hear intruders, sense temperature changes and feel pain. Hallucinating vividly in those sensory modes might lead us to wake up frequently in an unnecessary panic, or, even worse, over a long period we might evolve a threshold of tolerance that would cause us to block our real warnings. Our eyes can be closed, however, as we do not need to monitor our visual environment during sleep. And our bodies can be paralyzed, as is normal during REM sleep, because we do not need to move—in fact, we should not move until we awaken.

(The Author)

DEIRDRE BARRETT is a psychologist on the faculty of Harvard Medical School and author of the book *The Committee of Sleep* (Oneiroi, 2010).

GETTY IMAGES (*Frankenstein*); MARK J. WINTER *Photo Researchers, Inc.* (*benzene*); CHRISTOPHER COOPER *Corbis* (*periodic table*); IWAN BAAN (*building*)

Evolution, then, may help elucidate why certain brain areas are more or less active when we sleep. The pattern of activity explains why dreams have the characteristics they do—visually rich and logically loose. At first, these exciting physiological findings gave rise to a proliferation of theories that dreams were just an epiphenomenon, or side effect, of the brain patterns during slumber. Sleep researchers often referred to REM activity as "random," although no evidence suggested it was any more random than waking brain activity. Many theorists leaped to pronounce dreams "explained."

I reiterate: we would never dismiss waking thought so quickly. Knowing that our prefrontal cortex is active when we encounter a social prohibition does not explain away the subjective debate we experience when deciding how to respond. Likewise, describing a dream's content or its associated brain activity does not answer the question of its purpose. Brain researchers finally grasped this fact after a two-decade lull and in the past few years have begun studying dreams seriously again.

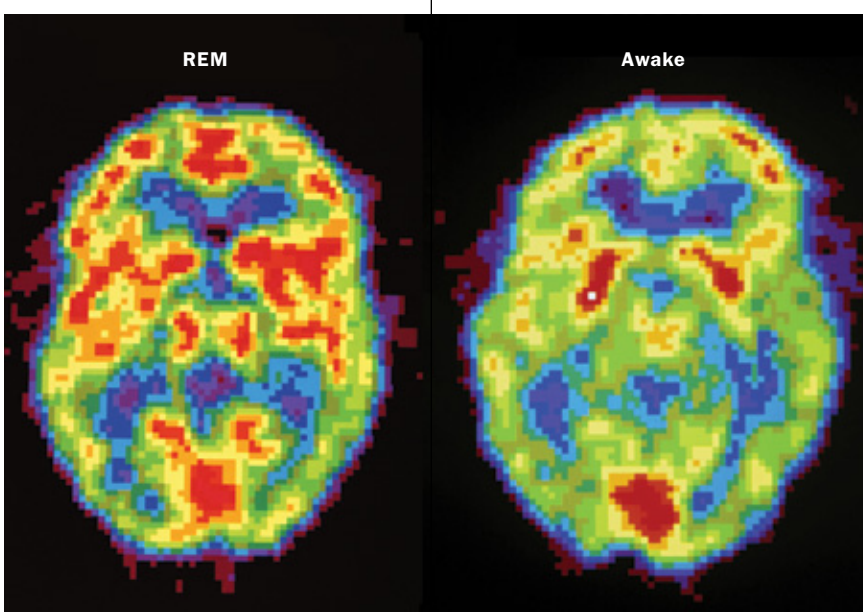
Sleep on It

By the 1990s a growing body of research suggested that slumber is important for consolidating new learning: even very early studies had shown that sleeping for a while after learning something new results in much better recall than after spending the same amount of time awake. More recent findings hint at a special role for REM sleep in memory consolidation. Studies of rats learning to navigate mazes have found that during REM sleep, brain activity mimics that of the awake rodent training in the maze, which suggests that circuits may be reinforced during REM sleep. In humans, too, research supports the role of REM sleep in memory. The more REM sleep subjects get after learning, the better they recall emotionally charged material [see "Quiet! Sleeping Brain at Work," by Robert Stickgold and Jeffrey M. Ellenbogen; Scientific American Mind, August/September 2008].

In 2009 psychologists at the University of California, San Diego, examined whether REM facilitated more than just memory when learning. They gave their subjects a test that required creative problem solving and then dropped hints about the answers. The subjects then spent some time either awake, in non-REM sleep only or in REM sleep before taking the test again. The REM sleep group showed the most improvement on their creative solutions to the previously presented problems.

The same year in Robert Stickgold's lab at Harvard University, a team led by postdoctoral researcher Ina Djonlagic had subjects learn a complicated system of weather prediction. The students were shown a combination of images, each representing a probability of sun or rain. The students did not know the meaning of the images, but they attempted to figure them out through trial and error by predicting an overall chance of sun or rain and getting feedback on their answers. The researchers found that subjects who nodded off before doing the task again were more likely to discover the general rule behind the images' meaning through an "aha!" type of insight than those who stayed awake. In addition, their heightened performance, as well as their ability to explicitly articulate that they had grasped the general rule, was correlated with the amount of REM sleep they had gotten.

Further research confirms that REM sleep aids in problem solving. In a series of ongoing studies in the same Harvard lab, postdoctoral researcher Erin Wamsley asks subjects to navigate a virtual maze. After some practice, they get either a waking break, REM sleep or a non-REM sleep period. As Wamsley reported at the 2011 SLEEP conference, only REM sleep



Dreams occur in rapid eye movement (REM) sleep, during which the brain is just as active as when we are awake. Here positron-emission tomography scans show the brain during REM sleep (*left*) and while awake (*right*). Activity is indicated by the color spectrum, with red indicating the most active areas and blue the least.

HANK MORGAN *Photo Researchers, Inc.*

sharpens participants' performance. In addition, when she wakes or interrupts them to ask what they are thinking or dreaming, the theme is often the maze—but only when this thinking occurs in REM sleep do subjects fare better the next time they tackle the real maze.

Because REM sleep is the stage during which dreams occur, these sleep studies imply that dreaming might have something to do with creative problem solving. Mounting experimental evidence, as well as countless anecdotes of solutions that popped up during dreams, supports this idea.

The first study on dreams and objective problem solving was conducted more than a century ago. In 1892 Charles M. Child of Wesleyan University asked 186 college students whether they had ever addressed a problem in a dream. One third said they had. The students reported playing a chess game, solving an algebra problem, detecting a bookkeeping error and translating a passage from Virgil while slumbering.

The next major breakthrough came when researchers decided to try seeding people's dreams with a specific problem. In 1972 sleep researcher William Dement of Stanford University asked 500 of his students to spend 15 minutes a night trying to solve brainteasers, making sure that they fell asleep with an unsolved problem on their mind. Students reported having 87 dreams, seven of which solved a brainteaser.

Such puzzles are a useful tool for testing creative problem solving because people are likely to get stuck before having an "aha!" moment of insight. Yet these brainteasers may be beyond the ability of some subjects, and they are also not of great personal import. In Dement's study, which lasted three nights, all the correct answers came during the first night. He surmised that students lost motivation quickly on problems of little relevance to their lives. Therefore, in my own research

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Brain areas that restrict our thinking to the logical and familiar are much less active during REM sleep. Such disinhibition is a crucial part of creative thought.

in 1996, I took a different approach. I asked students to select their own objective problem. They recorded their dreams for a week and noted the ones they thought addressed the issue or contained a satisfactory solution. Two research assistants also judged whether the dreams focused on or solved the problems.

Most of my subjects chose problems that appeared simpler than Dement's brainteasers. Half of them had dreams they felt touched on their concern, and one third dreamed a solution to it. Judges rated only slightly fewer dreams as tackling or solving problems. Although a number of the problems had to do with homework or mundane tasks such as rearranging furniture, some of the most interesting solutions came up in dreams about major life decisions. For instance, this dilemma was rated as solved by both the dreamer and the judges:

> ***Problem:*** I have applied to two programs in clinical psychology and two in industrial psychology because I can't decide which field I want to go into.
> ***Dream:*** There's a map of the U.S., and I'm in a plane flying over this map. The pilot says we're having engine trouble and need to land. We look for a safe place on the map, indicated by a light. I ask about Massachusetts, which we're right over, but he says that all of Massachusetts is very dangerous. The lights seemed to be farther west.
> ***Solution:*** I woke up and realized that my two clinical schools are both in Massachusetts, where I have spent my entire life and where my parents live. Both industrial programs are far away, in Texas and California. This is because originally I was looking to stay close to home, and there were no good industrial programs nearby. I realized that there is a lot wrong with staying at home, and funny as it sounds, getting away is probably more important than which kind of program I go into.

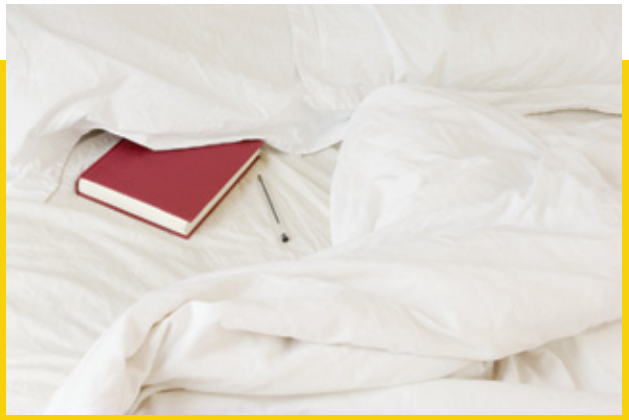
A Portal to Creativity

The all-time most famous dream example—Kekulé realizing that the structure of benzene was a closed ring after dreaming of a snake made of atoms taking its tail in its mouth—illustrates the two distinctive features of problem solving in dreams. Recall that the brain areas that usually restrict our thinking to the logical and familiar are much less active during REM sleep. Many studies of creativity suggest that such disinhibition is a crucial component of creative thought [see "The Unleashed Mind," by Shelley Carson; Scientific American Mind,

How to Train Your Dreams

Intentionally trying to dream about a particular problem, called dream incubation, increases the chance that you will come up with a solution. The term "incubation" was borrowed from ancient Greek practices at the temples of Asclepius. There the ill tried to have dreams that would tell them how to cure their malady. In Western psychology, here is how we harness our dreams:

1. Write down your problem as a brief phrase or sentence and place this note next to your bed. Also keep a pen and paper—and perhaps a flashlight—alongside it.
2. Review the problem for a few minutes before going to bed.
3. Once in bed, visualize the problem as a concrete image, if possible.
4. Tell yourself you want to dream about the problem as you drift off to sleep.
5. On awakening, lie quietly before getting out of bed. Note whether you recall any trace of a dream and try to invite more of the dream to return. Write it down.



TARA MOORE *Aurora Photos*

If you want a more elaborate process, add these steps to your incubation routine:

6. At bedtime, picture yourself dreaming about the problem, awakening and writing on your bedside notepad.
7. Arrange objects connected to the problem on your night table or on the wall across from your bed. *—D.B.*

May/June 2011]. Similarly, the high activity in the visual areas of the sleeping brain allows it to visualize solutions more readily than in waking thought. Kekulé had been stumped because all known molecules were straight lines with side chains, and he had assumed, wrongly, that benzene would follow suit.

My research confirms that dreamed solutions tend to have unusual visual characteristics. Through the late 1990s I scoured the existing literature on dreams, professional biographies and history books for examples of problem-solving dreams, and I queried working professionals as to whether they had ever had dreams that were useful in their jobs. Certain patterns emerged. Well over half of the visual artists said they had used dreams in their work. About half of fiction writers had. The numbers dropped off rapidly as the professions became more abstract. Within the sciences, inventors, engineers and others who benefit from visualizing problems in three dimensions were likelier to report helpful dreams. Some dreamers even had multiple examples of having awakened with a solution and had developed an explicit bedtime incubation routine.

In my present study, for which I reported preliminary results in June at the International Association for the Study of Dreams Conference, I investigated how dream-based problem solving might benefit working men and women more broadly. Professionals aged 21 to 69 attempted to solve real work-related problems in their sleep. These subjects seemed to dream about their problems with the same frequency as the college students I had observed in 1996; however, they reported less than half the number of solutions as compared with the students. The work-related problems may simply be more difficult than the college students'

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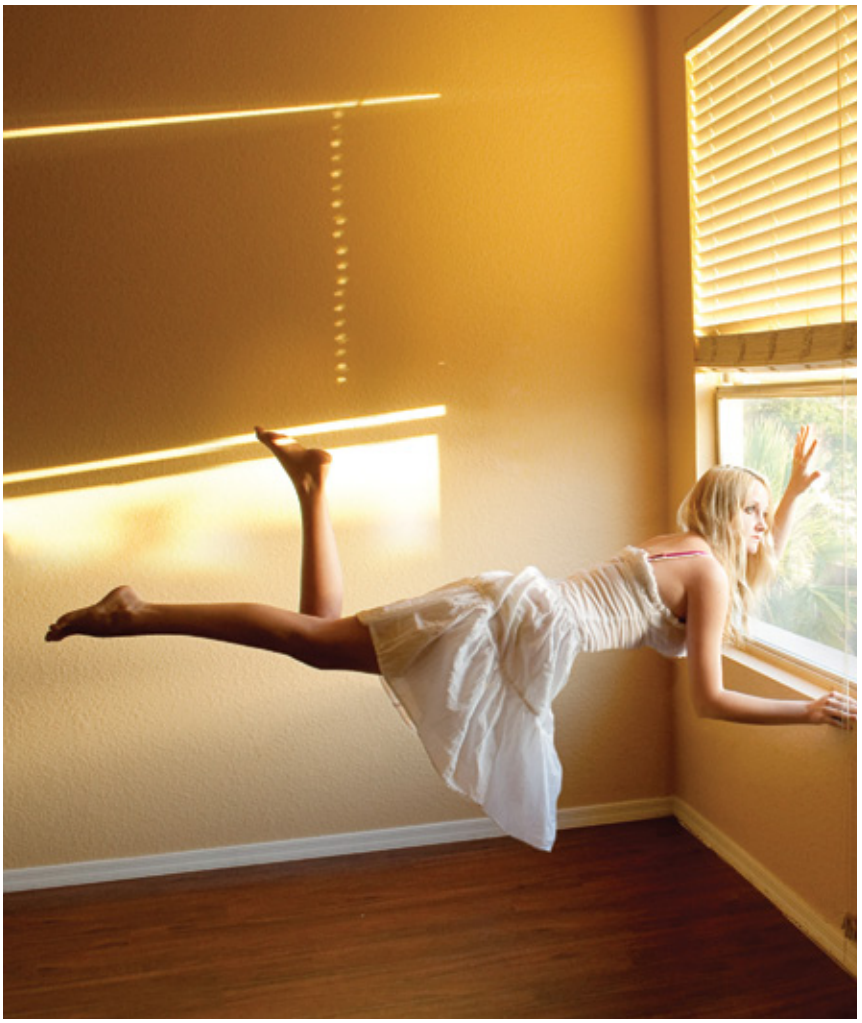
dilemmas, and because this group is older, the subjects may not recall as many dreams. A significant number of them, however, report having a useful dream after only one week of incubation practice.

Your Dreams

Shortly after my book *The Committee of Sleep* was published in 2001, I heard Newman recount his story on a PBS show about John Nash and the film *A Beautiful Mind*. A year later I was unexpectedly seated next to Nash at a dinner party. I asked him about the incident, which he remembered well. "Don actually included a footnote thanking me in the paper," Nash chuckled, "and he kept acting grateful, like I'd actually helped him when it was *his* dream." I came across that remark often in my survey. Solutions frequently came from a dream character—one computer programmer got repeated nocturnal lessons from Albert Einstein—and people had trouble taking full credit for what their dreaming mind had done. This tendency fits brain findings for REM sleep in which the dorsolateral prefrontal cortex, associated with perceptions of volition, is less active.

But we need not wait passively for inspiration to strike. We spend almost a third of our lives asleep—and almost a third of *that* time dreaming. My research suggests that in a short amount of time, people can learn to focus their dreams on minor problems and often solve them [*see box on opposite page*]. As for the bigger concerns, surveys find that all kinds of mysteries can be revealed in dreams—two Nobel Prizes resulted from dreams, after all. But even if you choose to leave your sleeping brain alone, pay attention: after nodding off, your brain in its altered state of consciousness is very likely already hard at work. M

WITH LOVE PHOTOGRAPHY *Getty Images*



Unlocking the *Lucid* Dream

Becoming aware of your sleeping self could relieve anxiety or tap the creative unconscious

By Ursula Voss

I moved my eyes, and I realized that I was asleep in bed. When I saw the beautiful landscape start to blur, I thought to myself, "This is my dream; I want it to stay!" And the scene reappeared. Then I thought to myself how nice it would be to gallop through this landscape. I got myself a horse … I could feel myself riding the horse and lying in bed at the same time.

So recounted a test subject in the sleep laboratory at the University of Bonn in Germany. This particular sleeper was having a lucid dream, in which the dreamer recognizes that he or she is dreaming and can sometimes influence the course of the dream. By measuring the brain waves of lucid dreamers, my colleagues and I are gaining a better understanding of the neural processes underlying this state of consciousness that exists between sleep and waking. In addition to providing clues about the nature of consciousness, research on lucid dreams is also beginning to suggest new ways to treat anxiety and learn complex movements while asleep.

Waking Frequencies during Sleep

Most people report having a lucid dream at least once in their life, and a small fraction of us have them as often as once or twice a week. Some individuals even develop routines to increase their chances of having a lucid dream [*see box on opposite page*]. But researchers who wanted to study lucid dreams were long confounded by the need to rely on subjects' self-reports. The process of recall is notoriously prone to distortion; for example, some people may confuse lucid dreams with the transient hallucinations that occur while falling asleep or waking up.

In 1975 sleep researcher Stephen LaBerge of Stanford University and his colleagues figured out a way to prevent such misinterpretation. Unlike the rest of the body, the eye and its movements are not inhibited during sleep. The researchers instructed subjects to move their eyes a certain way as soon as the sleepers recognized they were dreaming, for example, by rolling their eyes twice from left to right. These signals are easily distinguished from the rapid eye movement (REM) that occurs randomly during regular dreams. We still use this method today.

After a sleeper has signaled with eye movements that a lucid dream has started, researchers can investigate the corresponding brain activity using electroencephalography (EEG). In an EEG recording, electrodes attached to the skin of the head pick up the oscillating electrical signals that indicate that thousands or millions of neurons are firing in synchrony. Recent studies indicate that the brain's activity during lucid dreaming resembles that of waking consciousness.

In 2009 my team and I decided to take a closer look at the brain activity of lucid dreamers. In the sleep laboratory, we found what we believe to be an electrical signature of lucid dreaming—increased activity in the 40-hertz range (the "gamma band"), primarily in the frontal lobe, located behind the forehead. We tend to generate these high-frequency waves when we concentrate on a particular object. In addition to the frontal lobe, other regions of the cerebral cortex—the rippled mantle on the surface of the brain—play a major role in lucid dreaming. The frontal lobe seems to work in lucid dreams much as it does in the waking state, whereas areas in the parietal and temporal lobes exhibit patterns more typical of REM sleep.

Another striking feature in our study involved coherence—a rough measure of how coordinated the activity is in various areas of the brain. Coherence is generally slightly decreased in REM sleep, but not during lucid dreams. Think of the brain's activity during REM sleep as equivalent to a party with all the guests talking simultaneously. In lucid dreams, however, the party guests tend to converse with one another, and the overall background noise decreases.

Beyond Fantasies

Until recently, most experts thought of lucid dreaming as a curiosity—a fun way to act out wishful thinking about flying or meeting celebrities. But recent

CARLOS GOTAY Getty Images

Chronic nightmare sufferers often find their only source of relief is learning how to take control of their dreams. Becoming aware may create emotional distance.

FAST FACTS

Asleep yet Aware

1. Approximately eight out of 10 people have had a lucid dream, in which they were conscious of their dreaming, at least once.
2. Parts of the brain tend to work together more intensely during lucid dreaming than in other dream phases.
3. Lucid dreaming is useful for treating chronic nightmares and perhaps even anxiety.

Am I Dreaming?

Lucid dreams cannot be willfully induced, but you can increase the likelihood that you will have one. People who practice these techniques regularly are able to have one or two lucid dreams per week.

1. Throughout each day, ask yourself repeatedly if you are awake. When this habit becomes ingrained, you may find yourself asking the question in a dream—at which point your chances of realizing you are dreaming skyrocket.
2. Make a point to look in a mirror or reread a bit of text every so often as a "reality check." In dreams, our appearance is often altered and the written word is notoriously hard to pin down. You may carry the habit of checking for these dream signs into sleep, where they could alert you to the fact that you are dreaming.
3. Keep a dream journal by the bed and jot down the dreams you remember immediately on waking. Studies show that this practice makes you more aware of your dreams in general, and people who are more aware of their dreams are more likely to have a lucid dream.
4. Before falling asleep, focus intently on the fantasy you hope to experience in as much detail as possible. Research shows that "incubating" an idea just before bed dramatically increases the likelihood that you will dream about it. And if you suddenly notice that you are dancing with the movie star you hoped to meet, you might just realize you are having a dream and be able to take control of what happens next.

Adapted from the Lucidity Institute's Web site: www.lucidity.com

research has uncovered practical uses for lucid dreams. Chronic nightmare sufferers often find their only source of relief is learning how to take control of their dreams. A study in *Psychotherapy and Psychosomatics* in October 2006 found that those who learned how to increase their frequency of lucid dreams reported fewer awful dreams afterward, although the exact mechanism underlying the relief is unclear. Perhaps becoming aware during a bad dream allows sufferers to distance themselves emotionally from the dream's content. Some people may even become so adept at lucid dreaming that they are able to keep themselves from imagining frightening disaster scenarios while they are asleep.

In theory, lucid dreams could help alleviate generalized anxiety or the reaction to specific fear stimuli in everyday life (for instance, spiders) by allowing people to confront worries and frights in the safe environment afforded by knowing "it's just a dream." More research is needed to test this application.

Beyond therapeutic applications, lucid dreaming may also facilitate the learning of complicated movement sequences. In dreams, we are all capable of unusual actions. We can fly, walk through walls or make objects disappear. According to sports psychologist Daniel Erlacher of the University of Heidelberg in Germany, athletes can internalize complex motor sequences, such as those needed in the high jump, more quickly after targeted lucid-dream training.

Regular dreams have been shown to be involved in problem solving, so some researchers have asked if lucid dreams could be useful in focusing the dreamer's mind. A small study last year at Liverpool John Moores University in England suggests that lucid dreams are good for creative endeavors such as inventing metaphors but not for more rational exercises such as solving brainteasers. The lucid dreamers in the study were instructed to summon a "guru" figure, a wise character to serve as a kind of guide. Indeed, some of the subjects found their dream characters to be surprisingly helpful.

We still have much to learn about lucid dreaming. For example, we do not know under what circumstances these dreams appear most frequently or how to induce them more reliably. Once we do, we may finally harness these unique dreams' healing power and gain insight into the nature of consciousness. Lucid dreaming's potential for therapy, problem solving or pure entertainment could be limitless. M

(The Author)

URSULA VOSS is currently a visiting professor of psychology at the University of Bonn in Germany.

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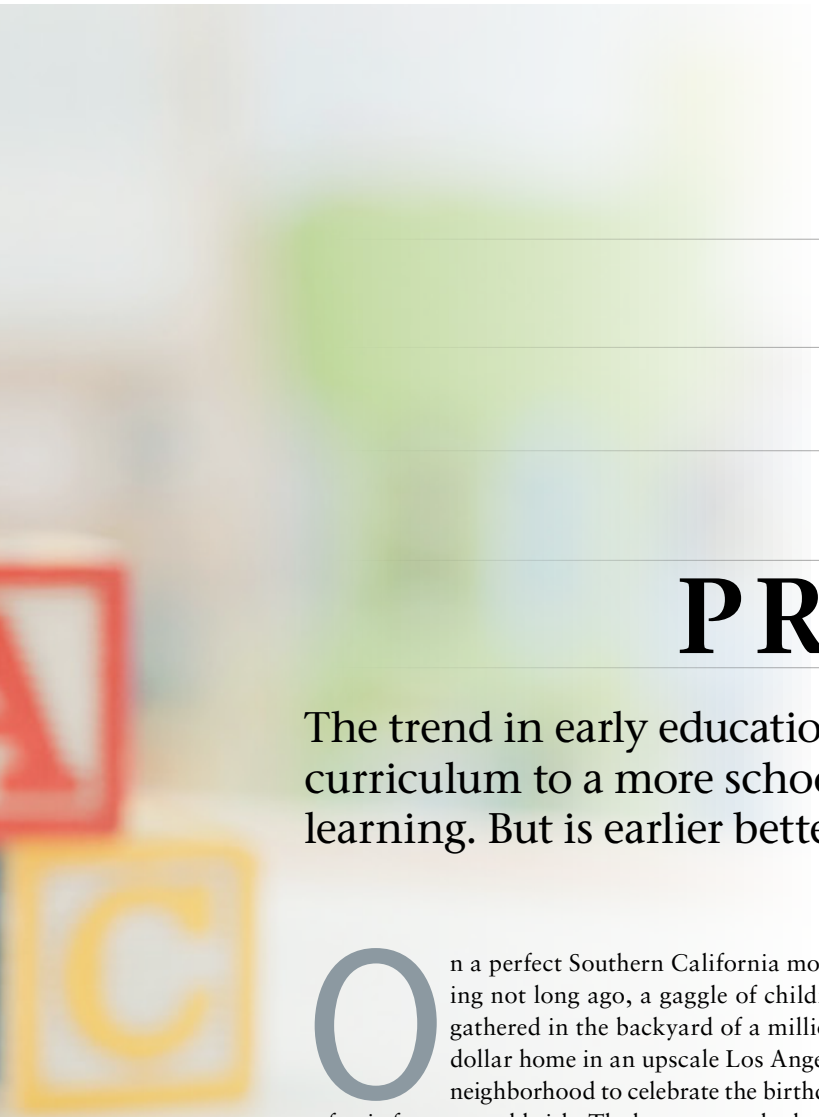
PHIL ASHLEY *Getty Images*



THE DEATH OF PRESCHOOL

The trend in early education is to move from a play-based curriculum to a more school-like environment of directed learning. But is earlier better? And better at what?

By Paul Tullis

On a perfect Southern California morning not long ago, a gaggle of children gathered in the backyard of a million-dollar home in an upscale Los Angeles neighborhood to celebrate the birthday of twin four-year-old girls. The host parents had rented a petting zoo for the day, and kids jumped gleefully in a bouncy castle out in the driveway. On the terrace, a few parents chatted beside an alluring spread of bagels, coffee and fruit.

Most of the kids at the party attend the same preschool. The father of one child enrolled there, where tuition is $14,300 a year for half a day, was asked what he likes about it.

"I like that my daughter can tell me what kind of whale it is we see in a movie," said the man, sporting a seersucker jacket. "They seem to be teaching things that other schools don't."

"You ask them what they did in school today," chimed in another dad, "and they're like, 'Oh, today we learned about pointillism.' There's a whole series on Picasso, a four-month project on Klimt."

The first father continued his praise. "You go in there, and they're sitting down, learning something," he said. "At other preschools, they're just playing."

These parents might be surprised to learn that "just playing" is in fact what nearly all developmental psychologists, neuroscientists and education experts recommend for children up to age seven as the best way to nurture kids' development and ready them for academic success later in life. Decades of research have demonstrated that their innate curiosity leads them to develop their social, emotional and physical skills independently, through exploration—that is, through play. Even animals as diverse as squirrels, horses and bears engage in, and cognitively benefit from, play [see "The Serious Need for Play," by Melinda Wenner; Scientific American Mind, February/March 2009].

The trend among preschools, however, is to engage children in activities that look more and more like school for older kids. Early-childhood educators are turning to a method known as direct instruction, which the National Institute for Direct Instruction, an advocacy group, defines as "teaching that emphasizes well-developed and carefully planned lessons … and clearly defined and prescribed teaching tasks." So children spend more time sitting, listening and fol-

AURORA PHOTOS

KATE MATHIS Getty Images

lowing instructions and less time playing pirates.

The National Association for the Education of Young Children, a Washington, D.C.–based organization that proposes standards for preschools, has changed its guidelines to focus more on specific achievements. In 1998 its standards "were more general in nature," says deputy executive director Barbara Willer. When the standards were last updated, in 2006, children were suddenly expected to demonstrate proficiency in 58 distinct topics in seven academic areas, including literacy, math and science. Although nobody is recommending either entirely free play or eliminating it altogether, even Willer advocates for balance: "Primarily focusing on seatwork or lecturing with little or no time for children to interact, explore, investigate and play is not an effective teaching strategy for active young children."

Nevertheless, the challenge of putting those guidelines into practice has tilted many preschool teachers toward traditional classroom activities such as lectures, flash cards and tests. "Scientists are baffled," says Alison Gopnik, a professor of psychology at University of California, Berkeley. "The more serious science we do, the more it comes out that very young children are not designed to do focused, goal-directed behavior we think of [as appropriate] for older children but are to a phenomenal degree very sophisticated about learning from the things and the people around them."

The Infant Intellect

Gopnik, with her colleagues Daphna Buchsbaum and Thomas L. Griffiths, demonstrated these sophisticated learning methods in a study published

FAST FACTS

Learning in Limbo

1» **A growing consensus among psychologists and neuroscientists maintains that children learn best when allowed to explore their environments through play.**

2» **Preschools are increasingly turning away from play-based learning to lectures and testing.**

3» **Placing heavy emphasis on academics early in life is not only out of line with how young brains develop, it might even impede successful learning later on.**

this year. The researchers showed two groups of children a toy that played music in response to a particular sequence of actions. With one group, an experimenter demonstrated several lengthy sequences of actions that made it play music; with the other, she pretended not to know how it worked. The kids in the first group imitated the experimenter. Although they successfully got the toy to play music, they did not figure out that only two actions embedded in the sequences were needed to produce sounds. The group without direct instruction, however, discovered the more efficient solution without the "teacher" ever having showed it to them.

In a similar study also published this year, developmental psychologist Laura Schultz of the Massachusetts Institute of Technology and her colleagues showed two groups of children a toy that did a number of things, including emitting squeaks. When left to play with it, the group for whom the experimenters demonstrated how to make it squeak could only make it squeak. The group given the toy without any direct instruction, however, made it squeak and discovered its other features, too. Direct instruction, these studies suggest, inhibits children's natural curiosity and their ability to learn.

Such expressions of inquisitiveness reveal how children investigate their world. For example, youngsters use dramatic ("pretend") play to try to exert control over their environment just as they grow strong enough to do so. Running around in circles, playing with blocks and climbing on a jungle gym may seem like exercise or goofing off to an adult, but several studies have shown that children infer a basic sense of physics through these activities. The possession of fine-motor skills—learned through activities such as drawing and cutting, which coordinate finger movement with visual perception—is one of the strongest predictors of academic success, according to a study last year by David Grissmer and his colleagues at the University of Virginia's Center for Advanced Study of Teaching and Learning.

Further evidence of children's innately sophisticated learning methods comes from long-term studies of how children acquire language. In a University of Kansas study in 1995, psychologists Betty Hart, Todd Risley and their collaborators tracked 42 families with one- and two-year-olds and recorded every verbal interaction between parents and children. They found no instances of direct teaching among the kids who went on to develop the widest vocabularies and richest use of language. As Peter L. Mangione, co-director of the Center for Child and Family Studies at WestEd in San Francisco, a nonprofit public research and development agency, puts it, "Storytelling, singing, playing, telling jokes—those are the building blocks of extensive vocabularies. Not direct teaching."

A report by the Alliance of Childhood found an average of 20 to 30 minutes a day of testing and test preparation among kindergarteners in Los Angeles and New York.

Preschool … or Precollege?

So why the shift to direct instruction at preschools today? Mangione sees two forces at work: "The perception is the earlier you start doing formal learning experiences, the better." A second factor, he and others agree, is standardized testing. The law passed by Congress in 2001 known as No Child Left Behind encouraged preschools to include more direct instruction in their curricula by mandating standardized tests in math and reading for all public school third graders. Schools failing to meet certain benchmarks face stiff penalties. Consequently, teachers in the earlier grades come under pressure to prepare kids for the coming high-stakes assessments.

Children enrolled in the federal Head Start preschool program for underprivileged children are also assessed as a result of No Child Left Behind. Yet, wrote Deborah Stipek, dean of Stanford University's School of Education, in 2006, "If the test used to assess early-childhood programs focuses on isolated skills, children are likely to be taught isolated skills." Such a shift, she continued, would tend to foster direct instruction.

Stipek was right: a report by the Alliance for Childhood, an international NGO promoting healthy child development, found an average of 20 to 30 minutes a day of testing and test preparation among kindergarteners in Los Angeles and New York. This past spring a New York City mother sued her daughter's $19,000-a-year preschool for failing

(The Author)

PAUL TULLIS has written for the *New Yorker, Wired, McSweeney's,* NPR's "Morning Edition," and more than 50 other print, digital and broadcast media outlets. He lives in Los Angeles.

to prepare the girl for the standardized tests that private schools rely on for kindergarten admissions. The suit cited an article in the *New York Times* as evidence of what has become an accepted fact of life among professional-class Manhattan parents in recent years, despite the absence of proof: admission to what is considered an "elite" preschool is a necessary first step to admission to the Ivy League.

Gopnik says the preschool teachers with whom she speaks regularly tell her they know that play is best for their small charges, but they feel squeezed between two sides. On one, as if confirming Mangione's hypothesis, is policy makers; on the other is parents.

It might seem ironic that this shift toward direct instruction and earlier introduction of academics is most visible among the children of some of the best-educated parents, at a time when American society as a whole is the best educated it has ever been—especially given all the science supporting play-based learning. But Gopnik points out that with many affluent people moving far away from family members when they enter adulthood and most women entering the workforce right away, fewer new parents have taken care of nieces, nephews and cousins, as they did in earlier times, before raising their own children. They may have no experience with the very young. "But what they have lots of experience with is going to school and work; they're really good at that, so it's natural they think that's what children should be doing as well. Not having seen what a three-year-old is like, they think they should put children in situations that are more academic."

Emphasizing the acquisition of skills such as early reading and geography comes with a trade-off—less time spent on social and emotional development, which are themselves important to a child's ability to learn.

Montessori Shir Hashirim, the place attended by the children of that L.A. birthday party, would appear emblematic of Gopnik's notion. Housed in a small, craftsman-style bungalow tucked between an apartment building and a recording studio a few blocks from the Hollywood Freeway, the school is considered one of the most exclusive preschools in the city, with pupils coming from the wealthiest neighborhoods. Inside, posters of well-known works by Picasso, Matisse, Léger and van Gogh cover walls freshly painted in bright colors. Soon after I sit down on a small, blue stool to observe the children, someone offers me an espresso.

This Montessori school is ostensibly based on an educational program developed by an Italian woman of that name early in the 20th century, which encourages children to discover new concepts using "materials that develop their cognitive powers through direct experience," in the words of the American Montessori Society. But in the first few minutes of observation, it is clear that direct instruction is part of the program.

One five-year-old boy is quizzed on the human skeleton. A girl pores over flash cards of words composed of two consonants surrounding the letter a. She sounds them out slowly with the help of a teacher, who repeats the sounds more quickly and more closely together.

"Sad!" the girl finally says.

"Tomorrow you have to read the same words," the teacher informs her.

Another girl aged four or five, in a long magenta skirt and a sequined T-shirt, assembles a puzzle that forms a map of Asia. After putting the largest piece on the floor in front of her, she approaches a teacher for direction.

"Find Vietnam," the instructor says. The girl digs through the puzzle pieces and places Vietnam on the floor. She goes back to the teacher.

"What's next to Vietnam?" asks the grown-up. The little girl's eyes dart nervously about the room as she searches the recesses of her tiny mind for the answer.

"Cambodia," she says.

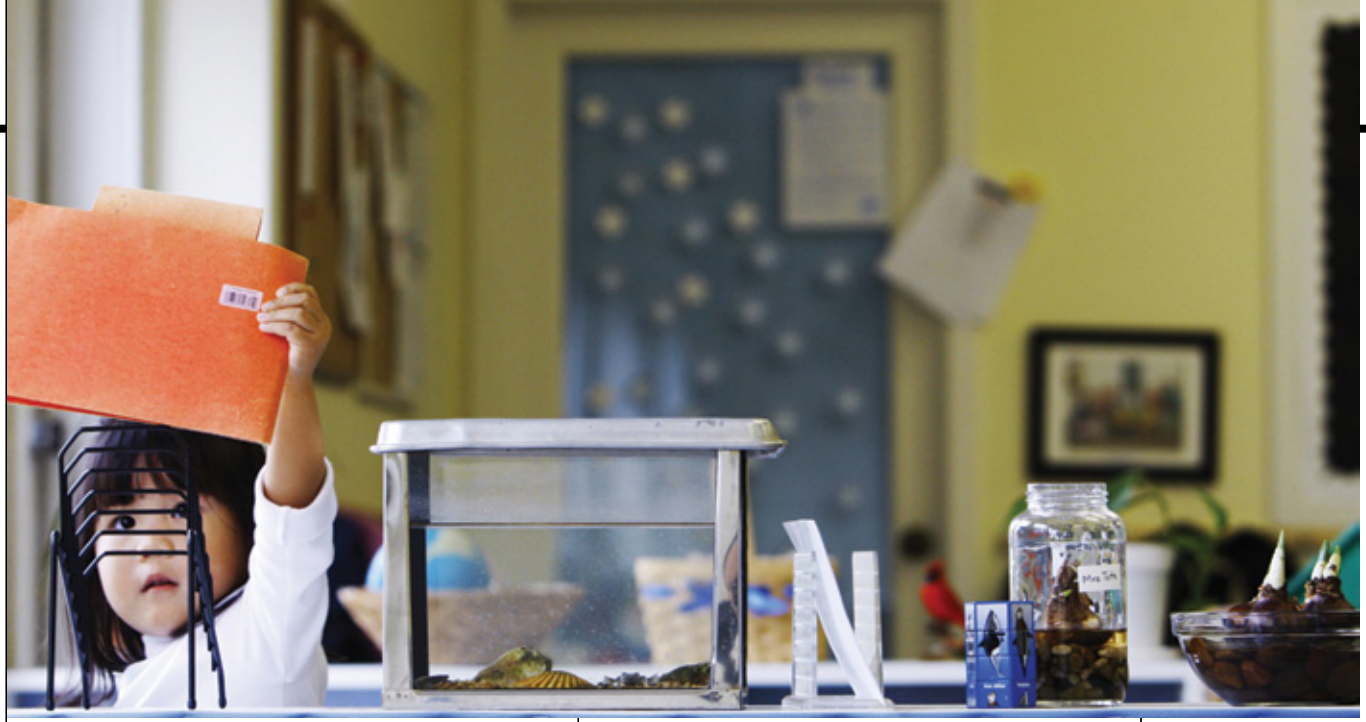
"Good," the teacher responds. "Now find Cambodia."

As the girl does so, I ask her what she knows about Vietnam.

"I don't know because I haven't been there," she tells me. "I've only been to Thailand."

Brains under Pressure

Salvatore Vascellaro teaches preschool teachers as a member of the faculty at New York City's Bank Street College of Education, one of the oldest and most well-regarded such schools in the U.S. Confirming what the girl had told me, he says, "Nothing is as rich for kids as when they engage the world physically." Although I had already spoken to Vas-



PABLO ALCADA *AP Photo*

cellaro, I was still impressed to see a preschooler identify the countries of Southeast Asia and assemble their shapes on a map. My seven-year-old sure could not do it. But, Vascellaro asks, "What would she do with that knowledge other than spout it back to adults? We want kids to draw relationships from what they see. To think and question and act on these things." A child's play is essentially improvisation—a chance to try out new concepts by imagining scenarios or thinking up ways to manipulate a toy.

More troubling is the idea that children may suffer when deprived of play. Emphasizing the acquisition of skills such as early reading and geography comes with a trade-off—less time spent on social and emotional development, which are themselves important to a child's ability to learn. "When we say every five-year-old must leave kindergarten reading," Vascellaro adds, referring to a policy some educational programs are adopting, "we've put some kids at a distinct disadvantage." The ability to read can come anywhere between the ages of three and seven and be considered normal. "If you're going to fail in kindergarten, boy, it's downhill from there."

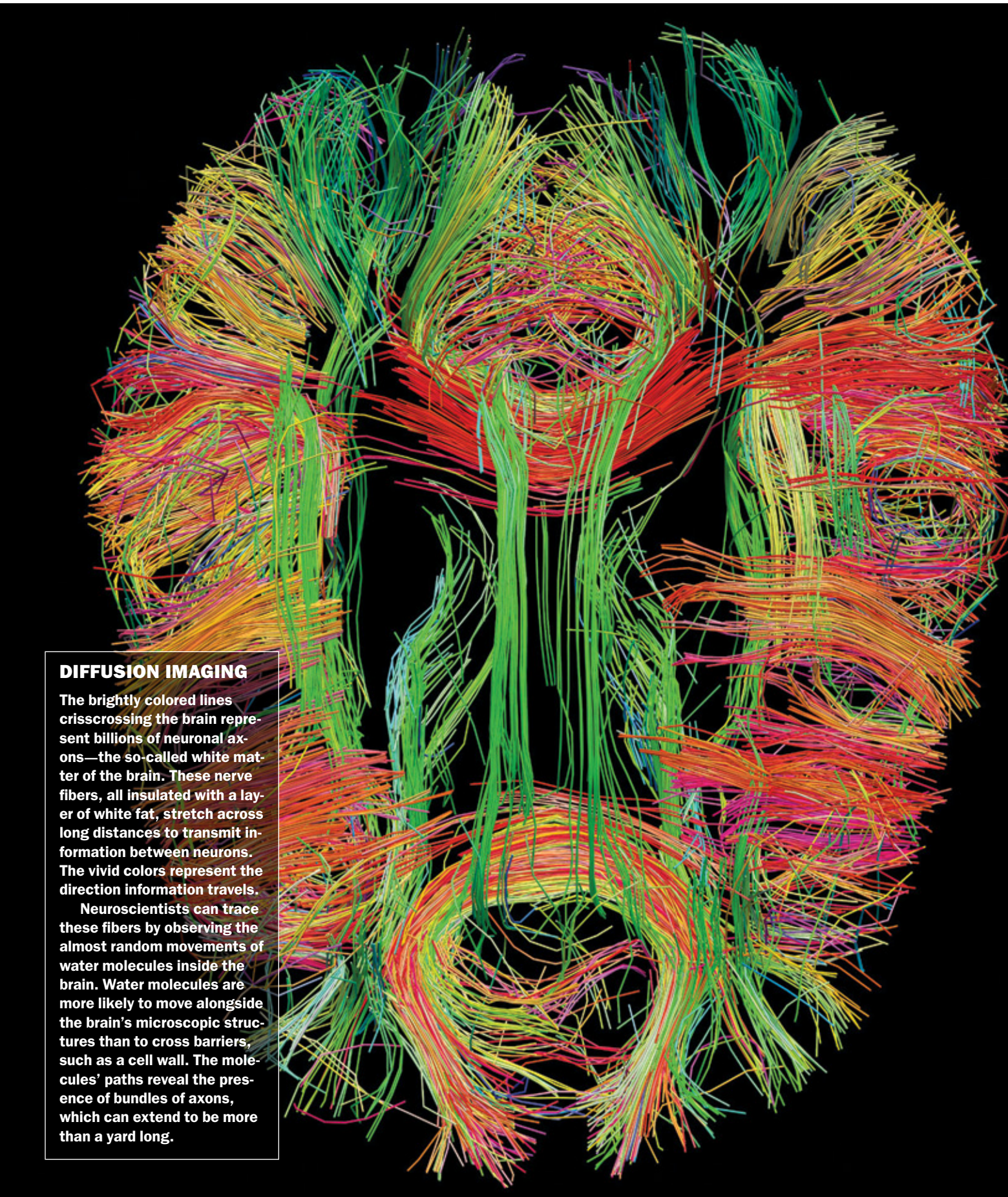
Early academic experiences can forge dramatic long-term links with mental health later on, as Lawrence Schweinhart, now president of the HighScope Educational Research Foundation in Ypsilanti, Mich., and his colleagues showed in 1997. They followed 68 three- and four-year-olds, all living in poverty, through age 23. Almost half of those in a heavily academic preschool went on to have emotional problems, compared with only 6 percent of those in the play-based preschool. The latter group also had fewer felony arrests and spent fewer years in special education diagnosed with emotional impairment.

Perhaps most disturbing is the potential for the early exposure to academics to physiologically damage developing brains. Although the brain continues to change throughout life in response to learning, young children undergo a number of sensitive periods critical to healthy development; learning to speak a language and responding to social cues are two such domains. Appropriate experiences can hone neural pathways that will help the child during life; by the same token, stressful experiences can change the brain's architecture to make children significantly more susceptible to problems later in life, including depression, anxiety disorders—even cardiovascular disease and diabetes. Bruce McEwen, a neuroendocrinologist at the Rockefeller University, notes that asking children to handle material that their brain is not yet equipped for can cause frustration. Perceiving a lack of control is a major trigger of toxic stress, which can damage the hippocampus, a brain area crucial to learning and memory.

That's probably not what the man in the seersucker jacket hopes for his daughter, who knows so much about whales. M

(Further Reading)

- **Einstein Never Used Flashcards: How Our Children Really Learn—And Why They Need to Play More and Memorize Less.** Kathy Hirsh-Pasek, Roberta Michnick Golinkoff and Diane Eyer. Rodale Books, 2003.
- **Montessori: The Science behind the Genius.** Angeline Stoll Lillard. Oxford University Press, 2005.
- **The Philosophical Baby: What Children's Minds Tell Us about Truth, Love, and the Meaning of Life.** Alison Gopnik. Farrar, Straus and Giroux, 2009.
- **Mind in the Making.** Ellen Galinsky. Harper Paperbacks, 2010.
- **Primal Brain in the Modern Classroom.** David C. Geary in *Scientific American Mind,* Vol. 22, No. 4, pages 44–49; September/October 2011.
- **Out of the Classroom and into the World: Learning from Field Trips, Educating from Experience, and Unlocking the Potential of Our Students and Teachers.** Salvatore Vascellaro. New Press, 2011.



DIFFUSION IMAGING

The brightly colored lines crisscrossing the brain represent billions of neuronal axons—the so-called white matter of the brain. These nerve fibers, all insulated with a layer of white fat, stretch across long distances to transmit information between neurons. The vivid colors represent the direction information travels.

Neuroscientists can trace these fibers by observing the almost random movements of water molecules inside the brain. Water molecules are more likely to move alongside the brain's microscopic structures than to cross barriers, such as a cell wall. The molecules' paths reveal the presence of bundles of axons, which can extend to be more than a yard long.

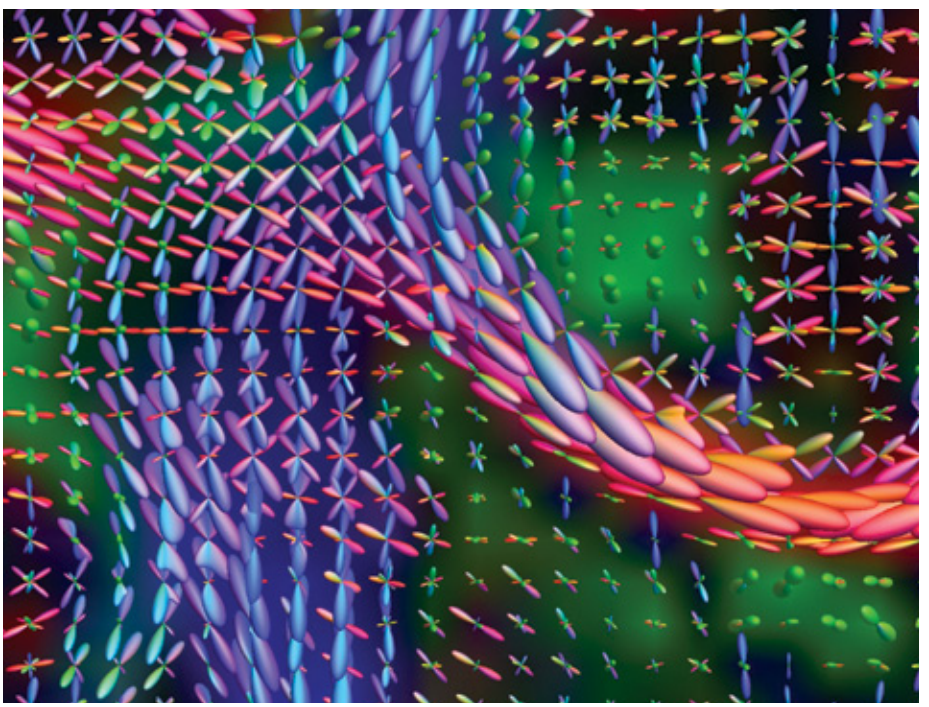
HEAD SHOTS

Artistry abounds in these 10 maps of the human mind

By Ann Chin and Sandra Upson

With 100 billion neurons and trillions of synapses, your brain spins neural webs of staggering complexity. It propels you to breathe, twitch, and butter toast, and yet we remain largely ignorant of how the brain does even these simple tasks—let alone how it stirs up consciousness.

To peer inside this three-pound lump of flesh, scientists manipulate a subtle trait of the body—its susceptibility to magnetic fields. Magnetic resonance imaging (MRI) has exposed the brain in stunning anatomical detail, and a sibling method, functional magnetic resonance imaging (fMRI), has offered insight into the mind at work. Here we explore how neuroscientists are using these methods to reveal new dimensions of the human brain.



OPPOSITE PAGE: COURTESY OF ARTHUR W. TOGA *UCLA-Harvard Human Connectome Project Consortium (www.humanconnectomeproject.org)*; THIS PAGE: COURTESY OF WALTER SCHNEIDER AND SUDHIR PATHAK *Learning Research and Development Center, University of Pittsburgh*; JAMIE CARROLL *iStockphoto (brain)*

HIGH-DEFINITION FIBER TRACTOGRAPHY

To define the lines in the image on the opposite page, an MRI machine charts the motion of water molecules at thousands of places in the brain, revealing the presence of fiber bundles, or tracts.

A major recent advance in diffusion imaging came from resolving how nerve fibers cross. The dragonfly-shaped elements shown at the near left indicate the orientations of two or more intersecting fibers, whereas the minnowlike ellipsoids signify one dominant fiber path.

MAGNETIC RESONANCE IMAGING

An MRI scanner harnesses the magnetic properties of hydrogen atoms to produce images of the body's interior. A magnetic field first causes the billions of hydrogen atoms in the human body to point in a single direction. The scanner then administers short pulses of energy that force the atoms to slide out of alignment. When they return to their original positions, they do so at different rates, creating magnetic signatures for various tissues. At the right, a scan of a brain after a stroke reveals a region of dead tissue, shown in red.

Functional MRI scans, which form the basis of the images on the opposite page, reflect the magnetism of blood vessels. When neurons spring into action, they consume energy, which increases the amount of blood traveling to them. The most widespread technique measures the differences in the iron content of oxygen-rich and oxygen-poor blood.

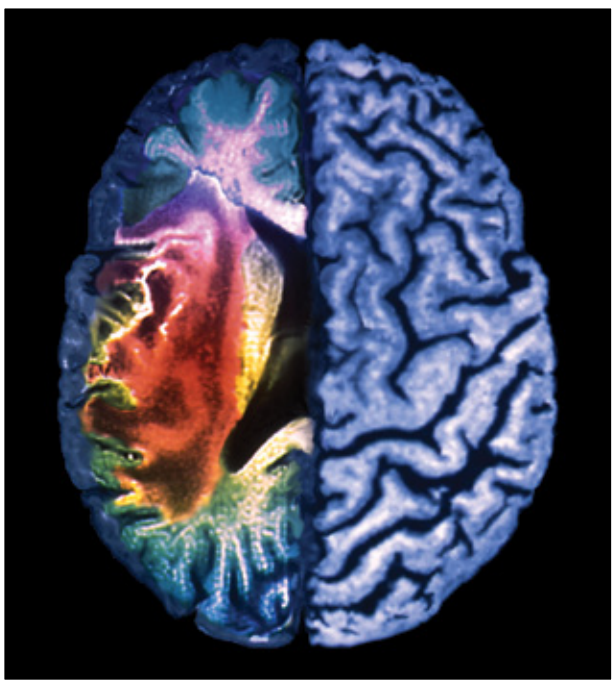
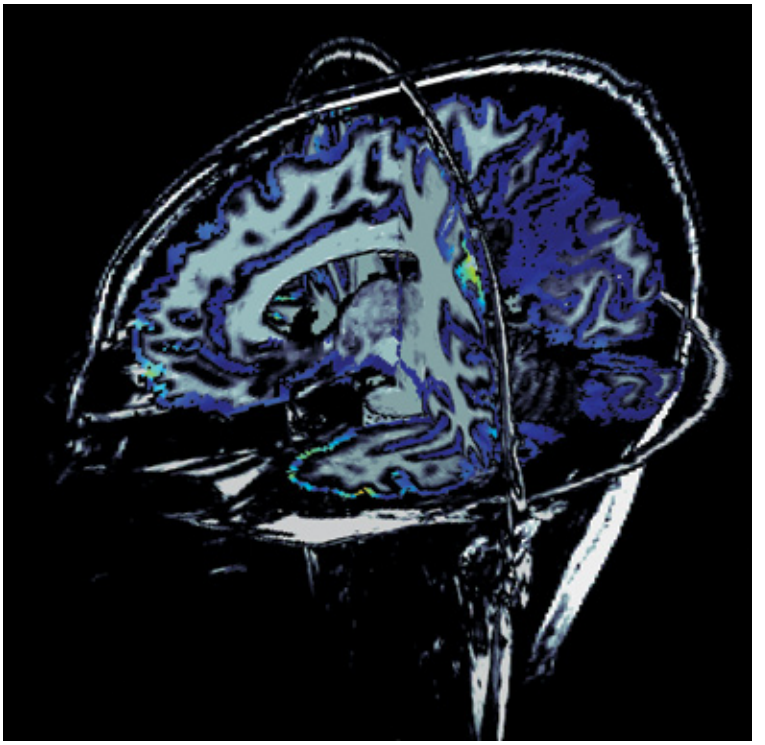
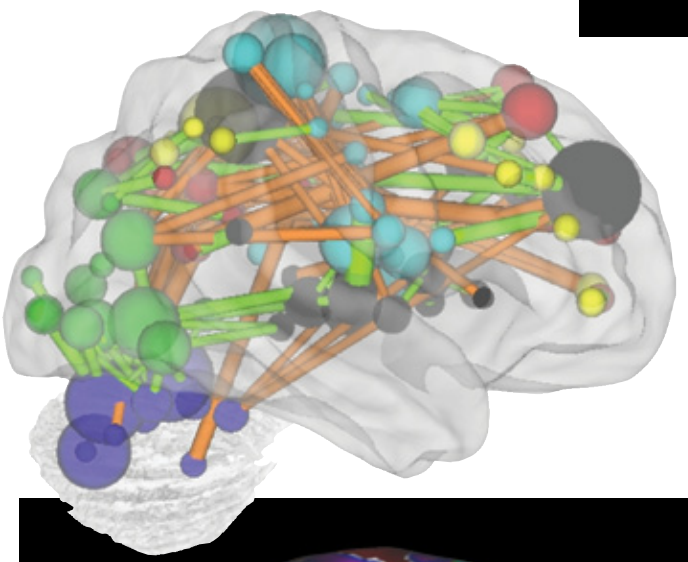


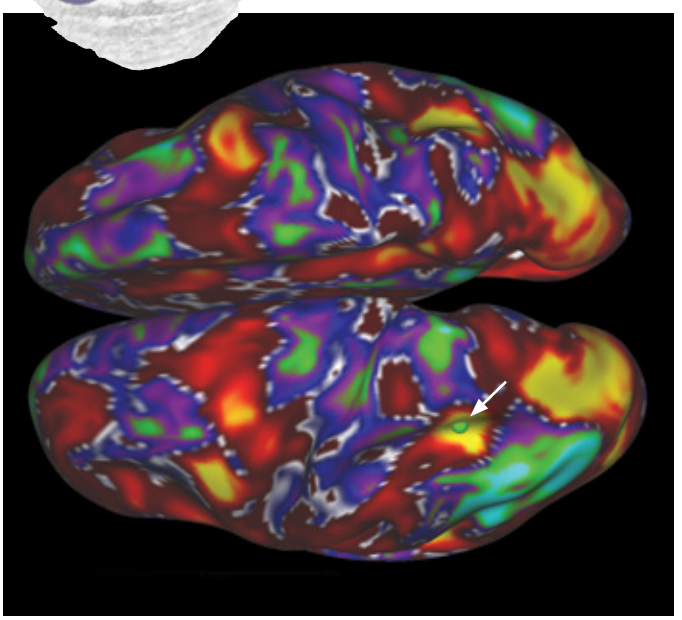
PHOTO RESEARCHERS, INC.

MAGNETOENCEPHALOGRAPHY

When neurons fire, they generate tiny magnetic fields. By surrounding the brain with extremely sensitive magnetic field detectors, neuroscientists can record that neural activity. Combining magnetoencephalography (MEG) data with an MRI view of the same brain provides anatomical detail. Because MEG directly observes neurons' behavior, as opposed to blood flow, it can capture brain events by the millisecond, as compared with a few seconds for an fMRI scan.







FUNCTIONAL CONNECTIVITY MRI

Unlike diffusion imaging, which traces physical links, these maps display how brain regions interact. Certain areas share a long history of working together to complete a task, even though they may not be directly connected by nerve fibers. Those functionally related regions also tend to activate in tandem when the brain is resting. The two images here were compiled from fMRI scans of a person at rest.

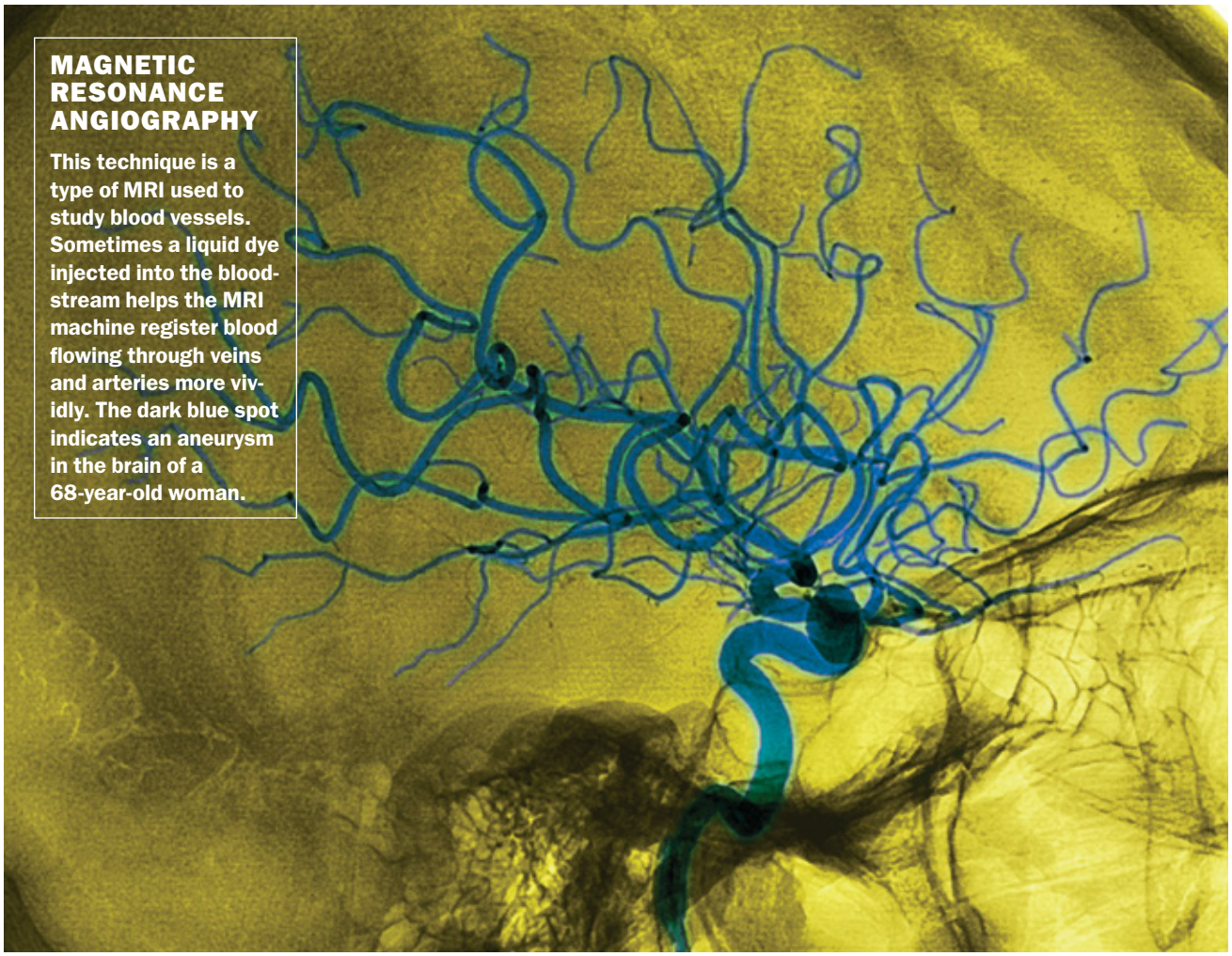
The diagram at the top left shows how fMRI images can predict a brain's age. The color of a sphere reflects its function, such as processing sensory data, and its size reflects its predictive power. The thickness of a line, which links interacting areas, shows how well the strength or weakness of that connection predicts a certain age. Orange links grow stronger as brains age, whereas light green ones weaken with time.

The activity of brain areas changes constantly according to distinct patterns. The image at the bottom condenses those fluctuating dynamics into one figure. Here the yellow region surrounding the small green sphere, believed to be involved in visual processing, activates in synchrony with areas colored yellow and red. When the area around the green sphere revs up, green and purple regions are much less active, and vice versa.

(The Authors)

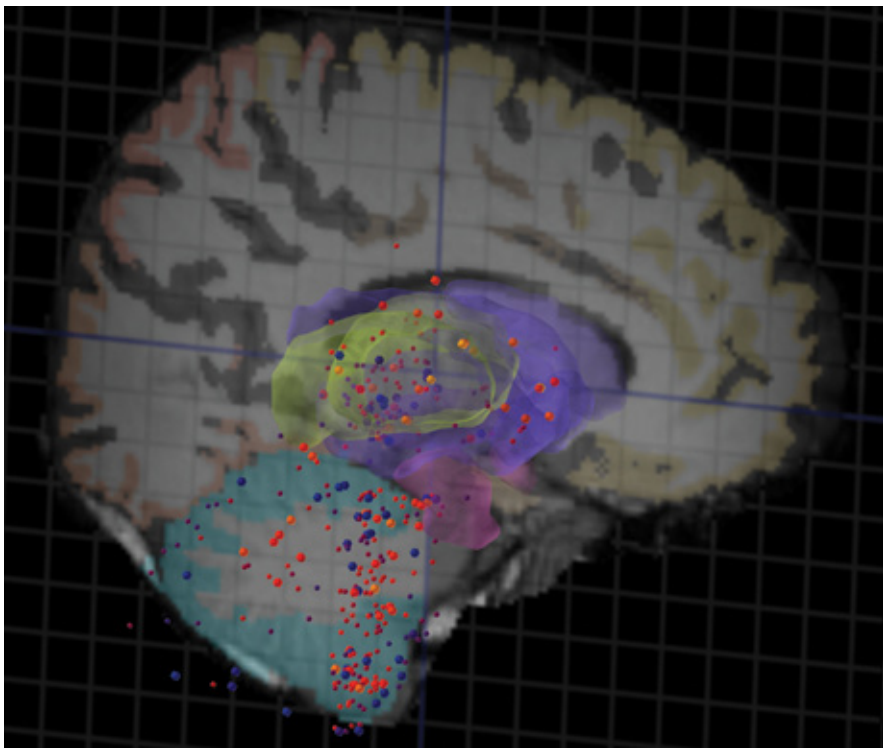
ANN CHIN is assistant photo editor and SANDRA UPSON is managing editor of *Scientific American Mind.*

TOP TO BOTTOM: COURTESY OF DIMITRIOS PANTAZIS *M.I.T.*; COURTESY OF SCIENCE/AAAS; COURTESY OF MATTHEW GLASSER AND DAVID VAN ESSEN *Washington University in St. Louis*



MAGNETIC RESONANCE ANGIOGRAPHY

This technique is a type of MRI used to study blood vessels. Sometimes a liquid dye injected into the bloodstream helps the MRI machine register blood flowing through veins and arteries more vividly. The dark blue spot indicates an aneurysm in the brain of a 68-year-old woman.



GENE EXPRESSION MAPPING

The Allen Human Brain Atlas catalogues the genes at work in the brain. Here the dots show the expression of *gpr88,* a gene that is highly active in the striatum. This area, in purple, is involved in movement. The light blue and yellow clouds denote the cerebellum and the thalamus, respectively. The spheres' colors reveal activity levels: expression is low for blue dots and high for red ones. *Gpr88* is considered a potential drug target for treating disorders such as Parkinson's disease.

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OPPOSITE PAGE: COURTESY OF MARISA ORTEGA AND ALFONSO RODRÍGUEZ-BAEZA *Autonomous University of Barcelona*

MICROSCOPY

Charting how blood flows through the brain is a mainstay of modern neuroscience and is key to elucidating the organ's structure. Microscopic blood vessels, shown here with the aid of a scanning electron microscope, supply the brain with energy and nutrients. The blood vessel at the top branches into tiny capillaries that distribute blood through the rest of the brain.

GANDEE VASAN *Getty Images*

Tiny subconscious eye movements called microsaccades stave off blindness in all of us—and can even betray our hidden desires

SHIFTING FOCUS

By Susana Martinez-Conde and Stephen L. Macknik

Look up from this page and scan the scene in front of you. Your eyes dart around, bringing different objects into view. As you read this article, your eyes jump to bring every word into focus. You can become aware of, and even control, these large movements of the eyes, which scientists call saccades. But even when your eyes are apparently fixed on something—say, on a tree, face or word—they are moving imperceptibly, underneath your awareness. And recent research shows that these minute, subconscious eye movements are essential for seeing.

If you could somehow halt these miniature motions, any image you were staring at would fade from view. In fact, you would be

Adapting to Sameness

At one time in your life, you may have scoured your house or apartment in search of your glasses, only to realize that you were wearing them. When you first put on your glasses, the touch receptors in the skin of your face and head gave you a rich sensory impression of their location, weight and tightness. But since then, you have not felt their presence. The reason is neural adaptation, in which neurons gradually decrease their output in response to an unchanging stimulus. Neural adaptation is a critical and ubiquitous process in the nervous system. It takes place in all the senses—vision as well as touch. Try to touch the elastic band of your sock without looking, while you keep your legs and feet still. If you missed it by at least a couple of inches, blame neural adaptation. After all, that band has not moved in a while. Your ability to see static objects would go away, too, if fixational eye movements did not constantly "wiggle" the images on your retina. *—S.M.-C. and S.L.M.*

rendered blind for most of the day. Although these eye movements have long baffled scientists, only recently have researchers come to appreciate their importance. Indeed, we now have garnered strong evidence that the largest of these involuntary meanderings, the so-called microsaccades, are critical to everyday vision.

Microsaccades are also providing new clues to neurological ailments that affect both eyesight and movement. Even more intriguingly, they can serve as a window into your mind. These seemingly random ocular shifts are not arbitrary after all: they can point to where your mind is secretly focusing—even if your gaze is aimed elsewhere—revealing hidden thoughts and desires.

FAST FACTS

Eyes in Action

1» **Even when you think your eyes are staring, fixed in space, they are actually on the go. Their miniature motions prevent you from being blind to most of what is out there.**

2» **Tiny "fixational" eye movements also support our ability to search a visual scene, in concert with the bigger shifts of our eyes of which we are often consciously aware.**

3» **Minute flicks of the eyes called microsaccades can reveal objects that attract our attention.**

Sleepy Stares

Researchers have known for centuries that the eyes move all the time. For example, in 1860 German doctor and physicist Hermann von Helmholtz suggested that "wandering of the gaze" prevented the retina, several layers of cells at the back of the eye, from becoming tired.

Movement near you may indicate that a predator is approaching or that prey is getting away. Animal nervous systems have evolved to detect such changes, which prompt visual neurons to emit electrochemical impulses. Because unchanging objects do not generally pose a threat, some animals are blind to unmoving objects; recall the *T. rex* in *Jurassic Park*. A fly sitting still on the wall is invisible to a frog, for example, but as soon as the fly is aloft, the frog can capture it with its tongue. Neuroscientist Jerome Lettvin of the Massachusetts Institute of Technology and his colleagues stated in their classic 1959 paper, "What the Frog's Eye Tells the Frog's Brain," that frogs "will starve to death surrounded by food if it is not moving."

TERRY VINE *Alamy (woman)*; ALAMY *(frog)*

As Helmholtz correctly proposed, an unchanging stimulus causes neurons to gradually stop responding to the input,

Minute movements shift the visual scene across the eyes, waking up neurons and preventing stationary objects from fading away.

a phenomenon known as neural adaptation [*see box on opposite page*]. Neural adaptation saves energy by reducing the metabolism in neurons that do not receive new information, but it also limits what we can perceive. Although human visual neurons can adapt to unchanging stimuli, our visual system copes with lack of change better than a frog's because human eyes create their own motion even when we fix our gaze. Fixational eye movements—which include drifts and tremor as well as microsaccades [*see box on next page*]—shift the entire visual scene across the retina, prodding visual neurons into action and preventing stationary objects from fading away.

In 1804 Swiss philosopher Ignaz Paul Vital Troxler was the first to report that deliberately focusing on something can make unmoving images in the surrounding region gradually fade away [*see box on this page*]. You experience this disappearing act every day because a purposeful stare can briefly reduce fixational eye movements. Because you are training your eyes on whatever is directly in front of you, you do not notice the problem.

In the late 1950s researchers first pinpointed a perceptual role for microsaccades: after suppressing all eye movements to stabilize images on the retina for extended periods, they superimposed microsaccadelike motions and found that doing so brought back normal eyesight. (For a description of the original way images were stabilized, see page 53.) Other research teams, however, struggled to duplicate the results. For decades, many vision scientists even doubted whether microsaccades had a part in maintaining and restoring vision.

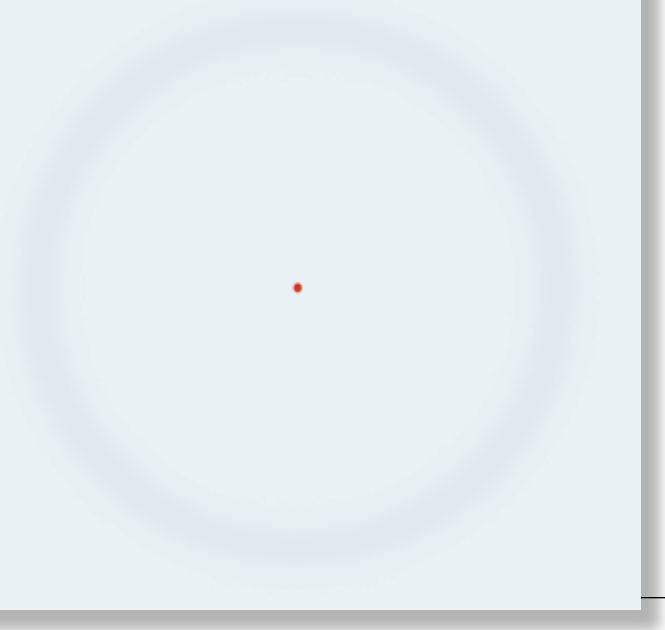
Shaken Awake

Then, in the late 1990s, researchers tried another approach. They began to investigate which neuronal responses, if any, microsaccades might be generating in the brain. Starting in 1997, along with Nobel laureate David H. Hubel of Harvard Medical School, we trained monkeys to stare at a small spot on a computer monitor, which also displayed a bar of light elsewhere on the screen. As the monkeys stared, we recorded their eye movements and the electrical activity from neurons in two visual brain areas: the lateral geniculate nucleus, a relay station between the retina and visual areas of the brain, and the primary visual cortex at the back of the brain [*see box on page 55*]. These experiments, published in 2000 and 2002, showed that microsaccades increased the rate of impulses from neurons in both visual regions. They do so by moving stationary stimuli, such as the bar of light, in and out of the region of visual space that activates a given neuron. Microsaccades essentially help to refresh an image to prevent it from fading. Other researchers documented similar effects in other parts of the visual system.

A few years ago we set out to link microsaccades with visibility using a different technique. In a version of Troxler's fading task, we asked people to fixate on a small spot and release a button when they saw a black-and-white patch in their peripheral vision. They pressed the button when the patch disappeared. The patch would vanish and then reappear as each person naturally fixated more—and then less—as they performed the task. Meanwhile we measured his or her eye movements using a high-precision video apparatus.

The Vanishing Ring

In 1804 Swiss philosopher Ignaz Paul Vital Troxler discovered that deliberately focusing on something causes surrounding stationary images to fade away. To elicit this experience, stare at the red spot while paying attention to the pale gray circle. The circle soon vanishes, and the red spot appears set against a white background. Move your eyes, and it pops back into view.



FROM "THE ROLE OF FIXATIONAL EYE MOVEMENTS IN VISUAL PERCEPTION," BY SUSANA MARTINEZ-CONDE, STEPHEN L. MACKNIK AND DAVID H. HUBEL, IN *NATURE REVIEWS NEUROSCIENCE*, VOL. 5: MARCH 2004

Beyond their role in our ability to see, microsaccades may reveal some of what we are thinking.

The subjects' microsaccades became less frequent and smaller just before the target vanished, showing that fewer microsaccades—or very small ones—lead to fading. In addition, microsaccades became more numerous and larger right before the target reappeared. The results, published in 2006, proved that these minute jumps counteract the visual fading of stationary objects and that bigger microsaccades produce the best visibility. And because our eyes are fixating—resting between saccades—more than three quarters of the time, microsaccades may be essential to our ability to see much of the time we are awake.

Where's Waldo?

As with saccades, microsaccades may also be involved in searching for something in a scene. Along with our colleagues at the Barrow Neurological Institute, we asked participants to look at pictures from Martin Handford's book *Where's Waldo?* and report to us when they succeeded in finding Waldo. At the same time, we recorded their eye movements. We found that the frequency of microsaccades was highest when people spotted Waldo. The results, published in 2008, revealed a direct link between microsaccades and how we search a scene.

We further determined, whether they were hunting for Waldo, exploring visually at will, or solving *Life* picture puzzles, that people tended to produce recurring saccades or microsaccades about 200 milliseconds apart. Because these different types of eye movements occur at similar intervals yet not simultaneously, we thought that the same neural structure might generate both. Complimentary experiments by vision scientist Martin Rolfs and his colleagues at the University of Potsdam in Germany led them to propose that the superior colliculus, a brain area directly responsible for orienting the eyes and head toward objects in the environment, might trigger both saccades and microsaccades.

This hypothesis received strong neurophysiological support in 2009. The superior colliculus is arranged in a map of visual space so that activity in the caudal (rear) portion produces large saccades in specific directions away from the center of gaze, whereas activity in the rostral (frontal) portion drives small saccades to eye positions near the center of gaze. Neuroscientists Ziad M. Hafed and Richard J. Krauzlis, then at the Salk Institute for Biological Studies, and Laurent Goffart of the Mediterranean Institute for Cognitive Neuroscience in Marseille, France, recorded impulses from individual neurons in the rostral part of the superior colliculus and found that they also triggered microsaccades. After the researchers blocked the output of this part of the brain with drugs, microsaccade rates dropped, affirming the structure's role in producing these movements.

Together with earlier behavioral studies conducted by Rolf's team and ours, among others, these findings demonstrate that saccades and microsaccades are turned out in a similar manner. Understanding the structure in the brain that creates microsaccades may bring scientists one step closer to understanding the engine behind much of our ability to perceive objects and locate them in a busy visual scene. This knowledge also gives us a place in the brain to look if something goes wrong.

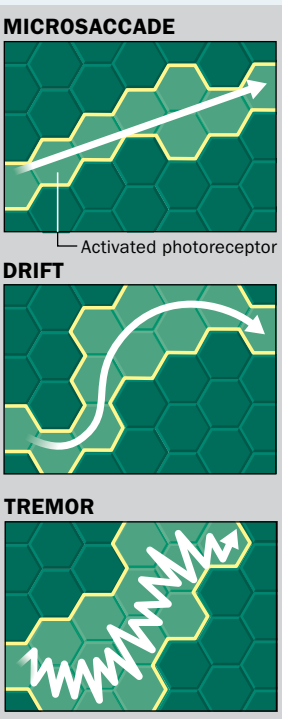
Errant Glances

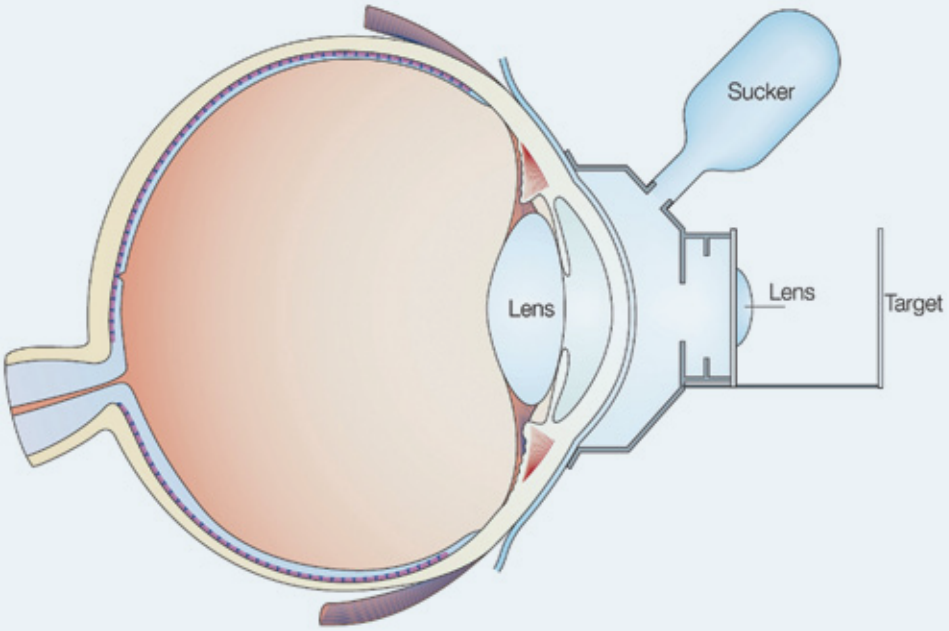
To see normally, the superior colliculus, along with other parts of the nervous system, must calibrate how much your eyes move when they fixate. Too few of these

JEN CHRISTIANSEN

More Ways to Move

When your eyes are staring at something, they move nonetheless. Scientists have identified three types of fixational eye movements: microsaccades (straight lines), drifts (wavy lines) and tremor (zigzags overlaying drifts). Microsaccades are the largest of the fixational eye movements, carrying an image across as many as several hundred of the eye's photoreceptor (light-detecting) cells. Tremor is the smallest of the fixational eye movements, its motion no bigger than the size of one of these cells. Drifts are slow meanderings that occur between the fast, linear microsaccades. Investigators have not yet identified specific functions for each of these eye movements in vision, however.





Stopping the Eyes

In the early 1950s some research teams succeeded in effectively freezing the visual scene by mounting a tiny slide projector onto a contact lens and affixing the lens to a person's eye with a suction device. In this setup, a subject views the projected image through this lens, which moves with the eye. With the use of such a retinal stabilization technique, the image remains still with respect to the eye, causing the visual neurons to adapt and the image to fade away. Nowadays researchers create this same result by measuring the eye's movements with a camera pointed at the eye. They transmit the eye-position data to a projection system that moves the image with the eye.

tiny shifts, as we have seen, can cause stationary objects to fade away. But too much motion can create blurred and unstable vision. Understanding how the oculomotor system achieves such a balance might one day enable doctors to make adjustments if it gets out of whack, as it can when certain disorders of the nervous system strike.

For instance, abnormal fixational eye movements often accompany amblyopia, the most common form of blindness in young people. People with amblyopia may have trouble seeing details even if their eyes are physically normal because of abnormal development in the visual parts of the brain. In severe amblyopia, too few microsaccades, along with excessive drift of the eyes, can cause even large parts of the visual scene to fade away when a person is focusing on something. In one case reported in the literature, a patient with an amblyopic eye "made saccades to revive the faded or blanked-out portions" of an image. The observation that saccades counteract fading in people with amblyopia is likely related to our finding that microsaccades do the same in healthy observers. Understanding the role of saccades and microsaccades in this disorder might one day spawn new treatments that ameliorate vision loss because of it.

Recently our laboratories teamed up with Case Western Reserve University neurologists R. John Leigh and Alessandro Serra to study microsaccade abnormalities in people with progressive supranuclear palsy (PSP), a disease similar to Parkinson's. In PSP, patients first display parkinsonian symptoms: they become unstable and fall often; their movement slows; and their bodies stiffen. In addition, however, PSP patients have trouble shifting their gaze between distant and near objects. The symptoms that characterize these diseases arise from distinctive patterns of neuronal degeneration. In Parkinson's, the loss occurs primarily in the substantia nigra, which contributes to body control. Gaze difficulties in PSP result from more widespread neuronal degeneration affecting the brain stem, frontal lobes, basal ganglia and cerebellum.

In its initial stages, PSP is often misdiagnosed as Parkinson's, which can be problematic because the standard treat-

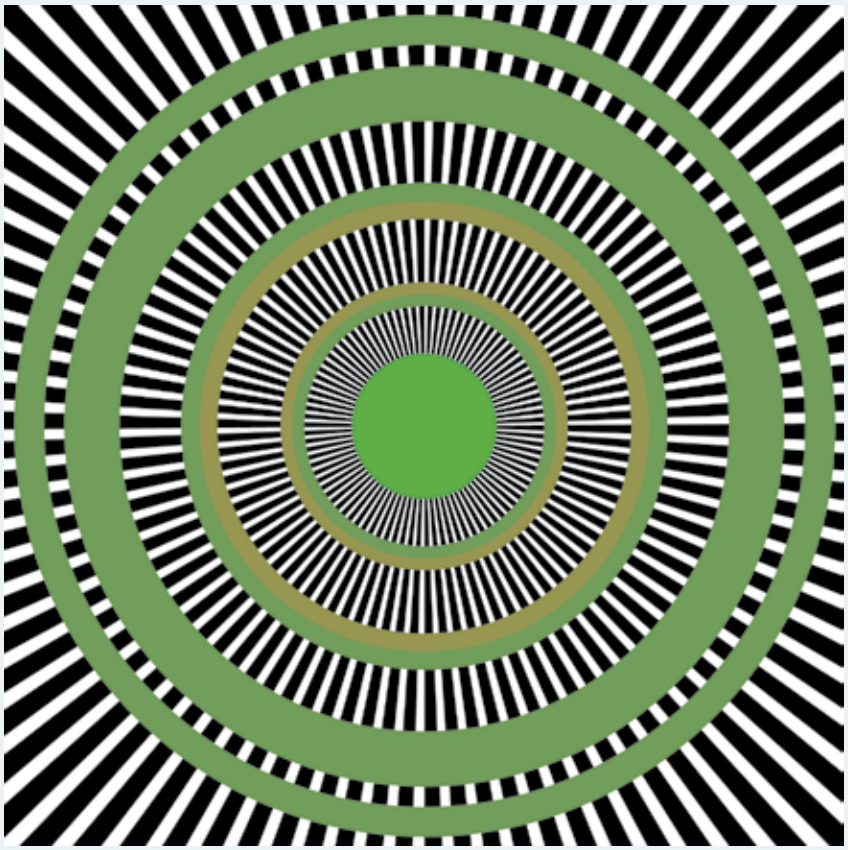
(The Authors)

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

FROM "THE ROLE OF FIXATIONAL EYE MOVEMENTS IN VISUAL PERCEPTION," BY SUSANA MARTINEZ-CONDE, STEPHEN L. MACKNIK AND DAVID H. HUBEL, IN *NATURE REVIEWS NEUROSCIENCE*, VOL. 5: MARCH 2004

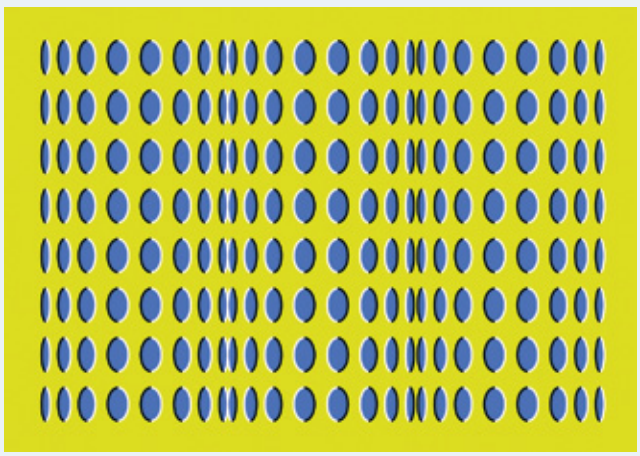
Mystery Solved

Look at the center of the image at the right and notice that the concentric green rings appear to fill with illusory motion, as if millions of tiny and barely visible cars were circling rapidly around a track. For almost 200 years artists, psychologists and neuroscientists have debated whether this type of striking illusory motion originates in the eye or in the brain, and for almost two decades the controversy has centered on the motion perceived in this painting, called *Enigma,* created by op-artist Isia Léviant. The evidence was conflicting until we found, in collaboration with our colleagues, neuroscientist Xoana G. Troncoso and graduate student Jorge Otero-Millan, both then at the Barrow Neurological Institute, that the perceived motion is driven by tiny shifts of the eyes called microsaccades.



***Enigma* illusion**

A few years ago one of us (Martinez-Conde) noticed that the speed of illusory motion in *Enigma* was not immutable across time but depended on how precisely a person fixed his or her gaze. If the individual held his or her eyes very still while staring carefully at the center of the image, the motion seemed to decrease and occasionally come to a full stop. Conversely, when he or she focused loosely, the movement seemed to speed up. Our previous research had shown that strict fixation suppresses the production of microsaccades, with dramatic effects on visibility. It followed that microsaccades may drive the perception of illusory motion under normal (loose) fixation conditions.



Roller illusion

To test this idea, we asked volunteers to stare steadily at a small spot at the center of an *Enigma*-like pattern while we measured their eye movements. Subjects had to press a button whenever the motion appeared to slow down or stop and release it whenever the motion sped up. As we predicted, microsaccades increased in frequency just before people saw faster motion and became sparser just prior to the slowing or halting of the motion. The results, published in 2008, proved for the first time that the illusory motion starts in the eye.

Microsaccades probably also underlie the illusory spinning in the picture at the left. If you let your eyes wander around the pattern, the three "rollers" will appear to spin. But hold your gaze steady on one of the blue spots, and the motion will slow or even pause. Because holding the eyes still stops the action, we speculate that microsaccades may be required to see it.

—S.M.-C. and S.L.M.

COURTESY OF JORGE OTERO-MILLAN *Barrow Neurological Institute (top);*
COURTESY OF AKIYOSHI KITAOKA *Ritsumeikan University (bottom)*

ment for Parkinson's, L-dopa, does not work in these patients. In research published earlier this year, we showed that the eye movements produced by PSP patients are different from those in healthy subjects and that normal microsaccades are very rare in PSP. We hope that our findings will ultimately help doctors diagnose accurately and early on who has this disorder. In addition, these results may assist researchers in evaluating the efficacy of drugs for PSP that are currently under development.

Private Eyes

Beyond their function in vision, microsaccades may reveal some of what we are thinking. Even when we are looking at one thing, our attention may be aimed at something else. Recent research suggests that microsaccades can reveal such objects of attraction because the direction of microsaccades, instead of being totally random, may point to them—even if your eyes are directed elsewhere. Hafed, then at McGill University, and his colleague vision scientist James J. Clark asked people to focus on a spot in the middle of a computer screen but to pay attention to another spot that appeared elsewhere. The peripheral spot changed color at the end of each trial, and every subject had to report the color change by pressing a button. Hafed and Clark found that the subjects' microsaccades were biased in the direction of their attention. Thus, your microsaccades may point toward that delicious doughnut you want to eat—or the attractive guy or gal standing across the room—even if you are averting your eyes from these temptations. These covert shifts of attention seem to control the direction of microsaccades.

Microsaccade frequency can also betray your attentional spotlight. Computational neuroscientist Ralf Engbert and cognitive psychologist Reinhold Kliegl of the University of Potsdam found that when something suddenly pops up in the periphery of your field of view, the microsaccade rate plummets briefly and then rapidly rebounds to a frequency faster than normal. The microsaccades also shift in the direction of the object. So both their direction and rate can signal sudden changes in your surroundings that attract your notice even if you look the other way.

You cannot read another person's mind by scrutinizing his or her microsaccades just yet. Only scientists working in a laboratory can detect and measure these minuscule eye movements. That fact may be welcome, assuming you do not want your co-worker—or spouse—decoding your thoughts. M

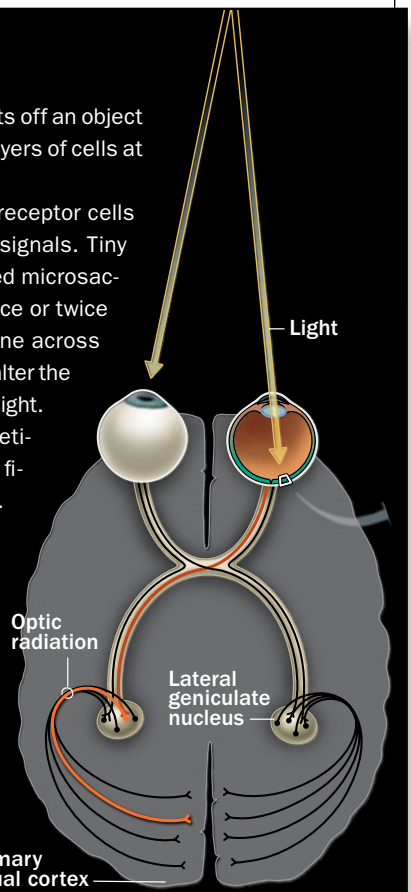
JEN CHRISTIANSEN

Moving Pictures

Vision begins when light reflects off an object and hits the retina, several layers of cells at the back of both eyes.

To the rear of the retina, photoreceptor cells transform light energy into neural signals. Tiny subconscious eye movements called microsaccades refresh the neural activity once or twice a second by shifting the visual scene across the retina. Microsaccades similarly alter the responses of other cells involved in sight.

The neural impulses from the retina zip along a cable of a million fibers—the optic nerve—to the brain. In the brain, visual signals stop first at the lateral geniculate nucleus in the thalamus. Then nerves called the optic radiations carry those signals to the primary visual cortex at the back of the brain, where neurons start to assemble and make sense of the information.



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STEVE McALISTER *Getty Images (hand turning switch)*; SCIENTIFIC AMERICAN MIND *(bolts)*

CULTURE OF SHOCK

Fifty years after Stanley Milgram conducted his series of stunning experiments, psychologists are revisiting his findings on the nature of obedience

By Stephen Reicher and S. Alexander Haslam

IN 1961 Stanley Milgram embarked on a research program that would change psychology forever. Fueled by a desire to understand how ordinary Germans had managed to participate in the horrors of the Holocaust, Milgram decided to investigate when and why people obey authority. To do so, he developed an ingenious experimental paradigm that revealed the surprising degree to which ordinary individuals are willing to inflict pain on others.

Half a century later Milgram's obedience studies still resonate. They showed that it does not take a disturbed personality to harm others. Healthy, well-adjusted people are willing to administer lethal electric shocks to another person when told to do so by an authority figure. Milgram's findings convulsed the world of psychology and horrified the world at large. His work also left pressing questions about the nature of conformity unanswered. Ethical

Small details could trigger a complete reversal of behavior—in other words, these studies are about both obedience and *dis*obedience.

concerns have prompted psychologists to spend decades struggling to design equally powerful experiments without inflicting distress on the participants.

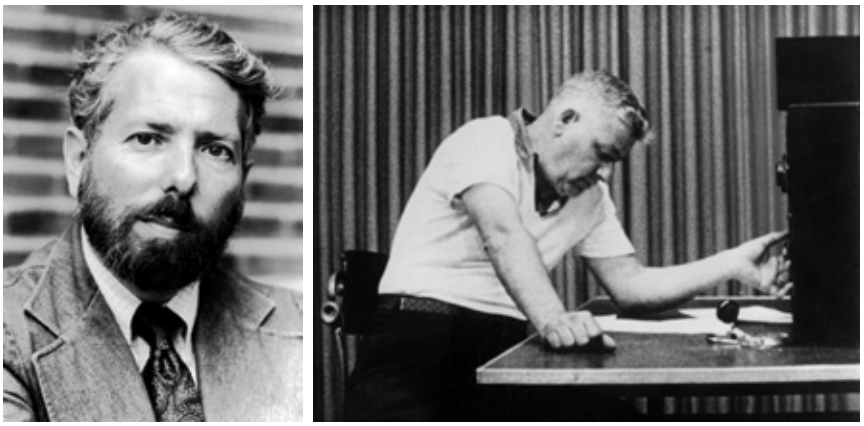
Researchers have now begun developing tools that allow them to probe deeper into his experimental setup. This work is pointing the way to new understandings of when and why people obey—and of the atrocities conformity can enable.

Obedience to Authority

When he began this project, Milgram had another goal in mind. He intended to assess whether some nationalities are more willing than others to conform to the wishes of an authority figure. His plan was to start studying obedience in the U.S. and then to travel to Europe to look for differences in behavior among populations there.

The topic of conformity was not new, and indeed Milgram had been heavily influenced by psychologist Solomon Asch, with whom he had studied in 1959 at the Institute for Advanced Study in Princeton, N.J. Asch had shown that when asked to make public judgments about the length of a line, people were often willing to bend to the views of their peers even when doing so meant defying the evidence of their own eyes.

Milgram suspected that Asch's results held hidden potential that might be revealed if he studied behaviors of greater social significance than simply judging lines. So Milgram designed an experiment in which participants—most of whom were men living near Yale University's psychology department, where the study was conducted—were told to act as a "teacher" assisting an experimenter in a study of memory. Their task was to administer a memory test to a learner, who in reality was an actor employed by Milgram. When this learner supplied an incorrect answer, the participant was to give him an electric shock. The ostensible goal was to investigate the impact of punishment on learning: Would the shocks improve the learners' performance or not?



Milgram (*at left*) tested people's compliance to an authority figure's orders. Participants, such as the one at the right, were told to give a memory test to actors posing as students and to deliver an increasingly powerful shock for each mistake, reaching potentially fatal voltages.

To administer the shocks, the teacher had in front of him a shock generator with 30 switches on its front panel. The buttons were arranged in ascending order from 15 volts, labeled with the words "slight shock," all the way up to 450 volts, ominously labeled "XXX." After each error the teacher had to depress the next switch to the right, increasing the jolt by 15 volts. Milgram was interested in seeing how far they would go. Would they administer a "strong shock" of 135 volts? What about an "intense shock" of 225 volts? Perhaps they would instead stop at 375 volts: "danger: severe shock." Surely, Milgram thought, very few subjects would go all the way—although people from some countries might go further than residents of other nations. In particular, he posited that Germans might be willing to deliver bigger shocks than Americans typically would.

Milgram was taken aback by what he found next. His initial pilot studies with Yale students showed that people regularly followed the experimenter's instructions. Indeed, the vast majority continued pressing switches all the way to the highest voltage—well beyond the point at which the shocks would prove lethal.

FAST FACTS

Shock and Awe

1» **Fifty years ago Stanley Milgram conducted groundbreaking experiments, discovering that ordinary people were willing to inflict lethal shocks on a stranger when asked to do so by an experimenter.**

2» **Initially seen as evidence of humans' blind obedience to authority, more recent analyses cast doubt on that interpretation.**

3» **Innovative experimental approaches are allowing psychologists to address ethical concerns about Milgram's original experiments and tackle pressing questions about conformity and power.**

Of course, the shock generator was not real, so the learners never really suffered. But the participants did not know this, so by all appearances Milgram's subjects seemed willing to deliver shocks sufficient to kill a person simply because they were asked to do so by a gray-coated lab assistant in a science experiment.

Startled by these findings, at first Milgram dismissed the results as a reflection of the particular nature of "Yalies." Only when he reran the studies with members of the broader American public did he begin to realize he was onto something big. In what became known as the baseline, or voice feedback, condition, the teacher sits in the same room as the experimenter. The learner is in another room, and communication occurs only over an intercom. As the shock levels increase, the learner expresses pain and demands to be released from the study. At 150 volts he cries out, "Experimenter, get me out of here! I won't be in the experiment any more! I refuse to go on!" Despite these pleas, 26 of the 40 participants, or 65 percent, continued administering shocks to the maximum, 450-volt level.

This discovery completely transformed Milgram's career. He abandoned his plans to run the study in Europe—if Americans were already so highly obedient, clearly Germans could not conform much more. Instead he concentrated on examining exactly what about his experiment had led ordinary Americans to behave so unexpectedly. As Milgram put it, he was determined to worry this phenomenon to death.

Science of Defiance

Popular accounts of Milgram's work most often mention only the baseline study, with its 65 percent compliance. In fact, he conducted a very large number of studies. In his book from 1974, *Obedience to Authority,* Milgram describes 18 variants. He also conducted many studies to develop the paradigm that were never published. In one pilot experiment the learner provided no feedback to the participants—and almost every teacher went all the way to 450 volts. Another variant, in which participants helped in the study but did not actually depress the lever to deliver the shock, produced similar results.

When the subjects sat in the same room as the learner and watched as he was shocked, however, the percentage of obedient teachers went down to 40. It fell further when the participant had to press the learner's hand onto an electric plate to deliver the shock. And it went below 20 percent when two other "participants"—actually actors—refused to comply. Moreover, in three conditions nobody went up to 450 volts: when the learner demanded that shocks be delivered, when the authority was the victim

Milgram, Arendt and the Holocaust

While Milgram was conducting his studies at Yale University, the young German philosopher Hannah Arendt was sitting in a Jerusalem courtroom watching the trial of Adolf Eichmann. Eichmann (*at right*), a key bureaucrat of the Holocaust, had arranged for Jews to be deported to the death camps. Everyone expected a person who had done such horrific things to look like a monster. But when he entered, people saw a slightly hunched, balding, and altogether nondescript character.

Arendt argued that this ordinariness was what made Eichmann truly frightening. He demonstrated that even the blandest functionary possesses the ability to do unspeakable things. She coined the phrase "the banality of evil," which, she argued, arises when people stop thinking about the consequences of their actions and instead concentrate on the details of the performance itself. She wrote that "Eichmann ... never realized what he was doing."

Milgram is clear about his debt to Arendt. He wrote that "Arendt's conception of the banality of evil comes closer to the truth than one might dare imagine." Indeed, a combination of historical, philosophical and psychological evidence supporting Arendt's idea made it a dominant view in academia, politics and popular culture alike.

In recent years, however, historians have cast doubt on Arendt's account of Eichmann, just as psychologists have begun questioning Milgram's notion of the "agentic state." In a recent biography of Eichmann, historian David Cesarani concludes that his protagonist not only knew what he was doing but even celebrated the slaughter of Jews. More generally, even though "ordinary people" may have helped perpetrate the Holocaust, the claim that they were simply onlookers with no awareness of their actions is hard to sustain.

—S.R. and S.A.H.

(The Authors)

STEPHEN REICHER is professor of psychology at the University of St. Andrews in Scotland. S. ALEXANDER HASLAM is professor of psychology at the University of Exeter in England. Reicher and Haslam both serve on the *Scientific American Mind* board of advisers. Along with Michael Platow, they are the authors of the recent *The New Psychology of Leadership.*

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of shocks, or when two authorities argued and gave conflicting instructions.

In short, Milgram's range of experiments revealed that seemingly small details could trigger a complete reversal of behavior—in other words, these studies are about both obedience and *dis*obedience. Instead of only asking why people obey, we need to ask when they obey and also when they do not.

In his various papers describing the studies, Milgram provides a rich and diverse set of explanations for his findings. He describes how the participants are presented with the experiments' worthy purpose to advance understanding, a goal the participants respect. He notes how a subject is often torn between the demands of the experimenter and the victim, with the one urging him to go on and the other pleading him to stop. He also expressed interest in the way other factors, such as the physical distance between the parties involved, might influence whom the participant listens to.

In the public eye, however, one theory has come to dominate: the idea that participants in the experiment enter into what Milgram terms an "agentic state" in which they cede authority to the person in charge. He developed this idea partly from Hannah Arendt's famous analysis of Adolf Eichmann, a perpetrator of the Nazi Holocaust [*see box on preceding page*]. As Milgram put it, "the ordinary person who shocked the victim did so out of a sense of obligation—a conception of his duties as a subject—and not from any peculiarly aggressive tendencies." In the face of authority, humans focus narrowly on doing as they are told and forget about the consequences of their actions. Their concern is to be a good follower, not a good person.

A computer simulation of Milgram's setup elicits behavior similar to that observed in 1961, without inflicting the same distress.

Milgram was a brilliant experimentalist, but many psychologists are profoundly skeptical of the idea of the agentic state. For one thing, the hypothesis cannot explain why the levels of conformity varied so greatly across different versions of the study. More broadly, this analysis focuses only on participants' obligations to the experimenter, although at several points in the studies they were also attuned to the fate of the learner.

When you examine the grainy footage of the experiments, you can see that the participants agonize visibly over how to behave. As Milgram recognized early on, the dilemma comes from their recognition of their duties to both the experimenter and the learner. They argue with the experimenter. They reflect the learner's concerns back to him. They search for reassurance and justification.

In fact, in designing the studies, Milgram anticipated this process. To make

Experimenting with Ethics

In a biography of Milgram, psychologist Thomas Blass of the University of Maryland described the furor that ensued after the *New York Times* ran an article on Milgram's studies in 1963. An editorial in the *St. Louis Post-Dispatch* described the studies as "open-eyed torture." The famous psychoanalyst Bruno Bettelheim called Milgram's work "vile" and "in line with the human experiments of the Nazis." He was even attacked in *The Dogs of Pavlov,* a 1973 play by Welsh poet Dannie Abse. One character, Kurt, describes the setup of the obedience studies as "bullshit," "fraudulent" and a "cheat."

Milgram responded robustly, claiming that "no one who took part in the obedience study suffered damage, and most subjects found the experience to be instructive and enriching." The data he collected from a questionnaire completed after each experiment are nuanced, however. Of the 656 participants in the studies, 84 percent said they were glad to have taken part, 15 percent were neutral, and a mere 1 percent were sorry. More than half

admitted to some level of discomfort during the studies, but only about one third admitted to having felt troubled by them since—in this latter group, only 7 percent agreed that they had been "bothered by it quite a bit." Although Milgram was probably right in saying that most people were fine, it is equally probable that a minority suffered to some degree.

Still, the fact that Milgram collected these data demonstrates that he was attuned to the ethical issues and aware of their importance. ***—S.R. and S.A.H.***

FROM "A VIRTUAL REPRISE OF THE STANLEY MILGRAM OBEDIENCE EXPERIMENTS," BY MEL SLATER ET AL., IN *PLOS ONE*, VOL. 1, NO. 1, E39; DECEMBER 20, 2006 (*virtual experiment*); CENTER FOR THE HISTORY OF PSYCHOLOGY, UNIVERSITY OF AKRON (*shock machine*)

Followers do not lose their moral compass so much as choose particular authorities to guide them through the dilemmas of everyday life.

it somewhat more controlled, he devised four verbal prods, which the experimenter would use if the participant expressed doubts. A simple "please continue" was followed by "the experiment requires that you continue" and then "it is absolutely essential that you continue." The most extreme prompt was "you have no other choice, you *must* go on."

As psychologist Jerry Burger of Santa Clara University has observed, of these four instructions only the last is a direct order. In *Obedience,* Milgram gives an example of one reaction to this prod:

> **Experimenter:** You have no other choice, sir, you must go on.
> **Subject:** If this were Russia maybe, but not in America.
> (*The experiment is terminated.*)

In a recent partial replication of Milgram's study, Burger found that every time this prompt was used, his subjects refused to go on. This point is critically important because it tells us that individuals *are not* narrowly focused on being good followers. Instead they are more focused on doing the right thing.

The irony here is hard to miss. Milgram's findings are often portrayed as showing that human beings mindlessly carry out even the most extreme orders. What the shock experiments actually show is that we stop following when we start getting ordered around. In short, whatever it is that people do when they carry out the experimenter's bidding, they are not simply obeying orders.

Morality and Leadership

The fact that we could so easily be led to act in such extreme ways makes it all the more important to explore when and why this happens. But at the same time, it raises acute ethical issues that in fact render the necessary research unacceptable [*see box on opposite page*]. As much as we wish to help society understand human atrocity, and thus prevent it, we also must not distress the participants in our studies who afterward will have to confront their own actions.

For a long time, researchers conducted secondary analyses of Milgram's data, studied historical events, and designed experiments with less extreme behaviors, such as having subjects be negative about job applicants or squash bugs. No matter how clever the design, none of these studies investigated how humans can inflict extreme harm on one another as directly as Milgram's did, nor did they have the same impact or social relevance.

Recently this stalemate has begun to shake loose. Mel Slater, a computer scientist at University College London, has developed a virtual-reality simulation of the obedience paradigm. He has shown that people behave much the same way in this environment as they do in real contexts, and he has suggested that his simulation can serve as a new venue for carrying out obedience experiments. Moreover, Burger has argued persuasively that those who obey the experimenter's instructions at 150 volts are most likely to carry on obeying right up to XXX. By stopping the trials at this level, then, we can address the same issues that Milgram did without actually asking people to inflict extreme harm on others—and having those individuals suffer later from the knowledge that they are willing to do so.

The key issue remains: how to define the circumstances that enable people to inflict pain on others. Milgram himself suggested that group formation and identification might play a role in determining whether we side more with authority or its victims. Other studies closely related to Milgram's have flagged these same processes–notably Philip Zimbardo's prison experiment at Stanford University in 1971 [see "The Psychology of Tyranny," by S. Alexander Haslam and Stephen D. Reicher; Scientific American Mind, October 2005]. Evidence suggests that we enact an authority figure's wishes only when we identify with that person and his or her goals. In essence, obedience is a consequence of effective leadership. Followers do not lose their moral compass so much as choose particular authorities to guide them through the ethical dilemmas of everyday life. Obedient people are not mindless zombies after all.

This radical reinterpretation of Milgram's studies clearly requires more data to support it, as well as further debate. Sadly, the need for this debate is no less pressing today than it was in 1961. With the recent government-led massacres in Libya and Syria and the shadows of Abu Ghraib and Guantánamo Bay hanging over us, we need more than ever to understand how people can be led to harm others—and how we can stop them. M

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SHAWN VAN DAELE *Getty Images*

In the Minds *of* Others

Reading fiction can strengthen your social ties and even change your personality

By Keith Oatley

We recognize Robert Louis Stevenson's Long John Silver by his commanding presence, his stoicism and the absence of his left leg, cut off below the hip. Although we think we know the roguish Silver, characters such as he are not of this world, as Stevenson himself admitted in *Longman's Magazine* in 1884. He described fictional characters as being like circles—abstractions. Scientists use circles to solve problems in physics, and writers and readers likewise use fictional characters to think about people in the social world.

Psychologists once scoffed at fiction as a way of understanding people because—well—it's made up. But in the past 25 years cognitive psychologists have developed a new appreciation for the significance of stories. Just as computer simulations have helped us understand perception, learning and thinking, stories are simulations of a kind that can help readers understand not just the characters in books but human character in general. In 1986 psychologist Jerome Bruner, now at New York University School of Law, argued persuasively that narrative is a distinctive and important mode of thought. It elaborates our conceptions of human or humanlike agents and explores how their intentions collide with reality.

Recent research shows that far from being a means to escape the social world, reading stories can actually improve your social skills by helping you better understand other human beings. The process of entering imagined worlds of fiction builds empathy and improves your ability to take another person's point of view. It can even change your personality. The seemingly solitary act of holing up with a book, then,

Although people usually read by themselves, fiction readers are not lonely. In fact, they tend to have more social support than do readers of nonfiction.

is actually an exercise in human interaction. It can hone your social brain, so that when you put your book down you may be better prepared for camaraderie, collaboration, even love.

Social Simulations

Long before computers were invented, stories functioned as the original virtual worlds. In 1594 William Shakespeare realized that a play essentially re-creates a social environment—he used the term "dream." In *A Midsummer Night's Dream,* Shakespeare's characters live in an imagined land in which dripping the juice of "a little western flower" into a sleeper's eye makes the sleeper fall in love with the first person he or she sees upon waking. In this dream world, the flower juice enables the selection of a life partner. Professor of English Elaine Scarry of Harvard University also advances the dream theme in *Dreaming by the Book*. She argues that rather than simply doling out descriptions of a world, a successful fiction writer offers "instructions" to start up a kind of waking dream.

But immersion in fiction need not be perceived as an isolating activity. Several years ago Raymond A. Mar, then a graduate student in psychology at the University of Toronto, decided to challenge the popular conception that people who read a lot of fiction are socially withdrawn bookworms who use novels as an escape from reality. Drawing on the social simulation idea, which I had described in two publications in the 1990s, Mar wanted to know whether people who read a lot of fiction might actually have *better* social skills than those who read little or none. Just as pilots gain practice with flight simulators, he reasoned, people might acquire social experience by reading fiction.

Along with our Toronto colleagues, psychologists Jacob Hirsh, Jennifer de la Paz and Jordan Peterson, Mar and I assessed the reading habits of 94 adults, separating fiction from nonfiction. Then we tested the volunteers on two types of social skills: emotion perception and social cognition. For the former, we asked subjects to try to discern a person's emotional state from photographs of just the eyes [*see box on opposite page*]. For the latter, participants answered questions about video clips of individuals interacting—for example, "which of the two children, or neither, in this clip belongs to the adult?" In this study, published in 2006, we found that the more fiction people read, the better they were at perceiving emotion in the eyes and, to a lesser extent, correctly interpreting social cues. These results drew the first strong connection between fiction reading and social skills, although we were not yet sure whether reading fiction was causing these individual differences or whether those differences existed in the first place.

A year later Mar published a piece of evidence more directly supporting the idea that reading fiction can improve social aptitude. Mar assigned 303 adults to read either a short story or an essay from the *New Yorker.* Then he gave all of them tests of both analytical and social reasoning. The former consisted of logic problems in verbal form; the latter asked people to draw conclusions from hypothetical social scenarios. Those who read the story

FAST FACTS

Bookworm Meets Socialite

1» Reading stories can fine-tune your social skills by helping you better understand other human beings.

2» Entering imagined worlds builds empathy and improves your ability to take another person's point of view.

3» A love affair with narrative may gradually alter your personality—in some cases, making you more open to new experiences and more socially aware.

COLIN ANDERSON *Getty Images*

performed better, on average, on the social reasoning test than those who read the nonfiction essay, suggesting that the fiction primed them to think about the social world. In contrast, the analytical reasoning scores were the same for both groups. Thus, even a brief bout of reading fiction can temporarily improve a person's social skills.

A New Perspective

Good social skills require having a well-developed theory of mind. Sometimes called mind reading, theory of mind is the ability to take the perspectives of other people, to make mental models of others, and to understand that someone else might have beliefs and intentions that are different from your own. Children start to acquire this ability at about four years old, when they can separate what someone else knows from what they know themselves. Theory of mind continues to develop throughout life. The ability to gauge emotion from pictures of just the eyes correlates with theory-of-mind skills, as does the capacity for empathy. Our 2006 study, with its test of eye expressions, suggests that the more fiction people read, the better they are at making mental models of others.

Still, the association we found between reading fiction and social ability could simply have reflected an affinity for fiction among people with good social skills. That is, devouring novels might be a result, not a cause, of having a strong theory of mind. To test this possibility, in 2009 we published a repeat of our earlier investigation with a separate group of 252 adults. This time, though, we measured the participants' so-called Big Five personality traits: extraversion, emotional stability, openness to experience, agreeableness and conscientiousness. We also assessed their social networks (social support), degree of social isolation and loneliness.

People who scored high on the personality trait of openness to experience did read slightly more fiction than those who scored higher on other traits. But when we controlled for this—statistically subtracted out this tendency and the effects of other individual differences—we still found a large and significant relation between the amount of fiction people read and their empathic and theory-of-mind abilities; it looked as if reading fiction improved social skills, not the other way round. Moreover, individuals who read predominantly fiction were not lonely. In fact, they were less socially isolated and had more social support than people who were largely nonfiction readers.

In 2010 Mar, along with psychologists Chris Moore of Dalhousie University in Halifax and Jennifer Tackett of the University of Toronto, followed up this work on adults with a study of 55 preschool children. They found that the more fictional stories preschoolers listened to and the more fictional movies they saw, the better they were on five tests of children's theory of mind. In one such test, a child is shown a toy figure of an adult and a picture of a carrot and a cookie. The child is asked which kind of snack he or she prefers and is then told that the toy figure prefers the other snack. Then the child answers the theory-of-mind question: The toy figure wants a snack, so which snack will the figure choose? To be correct, children have to provide an answer that differs from their own desires.

> The solitary act of holing up with a book is actually *an exercise in human interaction.*

Although scores on these tests were better among kids who listened to more stories or watched more movies, they were not higher among kids who watched a lot of television. The reason probably lies in the fact that TV shows explore fewer topics and themes that require adopting a character's point of view. They less often challenge the viewer to explain a protagonist's behavior, for example, or analyze the reasons for an outcome that a protagonist did not expect.

Our accumulating findings are providing increasing support for the hypothesis that reading fiction facilitates the development of social skills because it provides experience thinking about other people. That is, we think the defining characteristic of fiction is not that it is made up but that it is about human, or humanlike, beings and their intentions and interactions. Reading fiction trains people in this domain, just as reading nonfiction books about, say, genetics

Anxious? Annoyed? A person's ability to correctly read an expression from a snapshot of just the eyes reflects his or her social skills. Fiction fans do well at this task. Test yourself here: **www.glennrowe.net/BaronCohen/Faces/EyesTest.aspx**

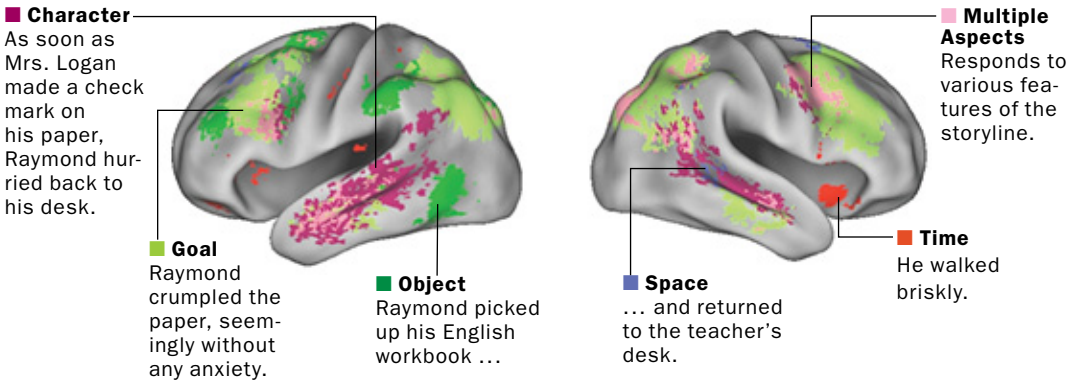
(The Author)

KEITH OATLEY is professor emeritus of cognitive psychology at the University of Toronto and is a fellow of the Royal Society of Canada. His most recent novel is *Therefore Choose* (Goose Lane, 2010).

MARTIN BARRAUD *Getty Images*

Stories on the Mind

The brain responds to fiction as if a reader were feeling or acting just as the character is in the story. Scientists correlated passages displayed in a functional MRI scanner with brain activity. The prefrontal cortex, an area behind the forehead concerned with goal-setting, reacted when a character initiated a new goal. The temporal cortex, at the brain's sides, responded to character switches and goal-directed actions. Other parts reacted to allusions to time, or to changes in a character's spatial location or dealings with objects, in keeping with their regular roles.



➥For an interactive graphic highlighting psychologically rich novels, visit **www.ScientificAmerican.com/mind/nov2011/fiction.**

or history builds expertise in those subject areas.

To test this hypothesis more fully, we plan to assign people to read either only fiction or only nonfiction books for several months. We will measure the social awareness of both groups before and after the reading period. If our theory is correct, the fiction readers should show significant improvement on social measures, and their scores should increase more than those who were exposed to just nonfiction.

Getting into Character

Fiction gets its power from a reader's emotional connection to the characters in a story—in a word, empathy. Scientists have traced the roots of some aspects of that tie in the brain. In a 2004 study, for example, neuroscientist Tania Singer and her colleagues from University College London found, using functional MRI, that brain areas such as the anterior insula and anterior cingulate cortex become active both when we feel pain and when we know that someone we love is in pain. These areas seem involved in the emotional aspects of pain.

The emotional empathy that is critical to our day-to-day relationships also enables us to picture ourselves living as the characters do when we read fiction. In fact, recent brain scans reveal that we internalize what a character experiences by mirroring those feelings and actions ourselves. In a study published in 2009 psychologists Nicole Speer, Jeremy Reynolds, Khena Swallow and Jeff Zacks of Washington University in St. Louis asked 28 volunteers to recline in an fMRI scanner and read a short story, presented one word at a time on a screen. When a subject read about something the protagonist did, the researchers found that the reader's brain responded as if he or she were performing the same action. When the words of a passage were about picking up or putting down an object—for instance, "Raymond laid down his pencil"—regions associated with grasping and letting go of an object with the hands were activated. These areas included the hand area of the premotor (motor planning) and of the somatosensory (body-sensing) cortices.

Other researchers have tried to home in on how fiction might tap into brain processes governing theory of mind. If narrative augments our ability to understand others, the brain regions concerned with following a storyline should overlap with those recruited in theory-of-mind tasks. To test this idea, earlier this year Mar, now at York University in Toronto, published a statistical review of 86 brain-scanning studies in which participants either had to comprehend a story, perform a theory-of-mind task based on a narrative or carry out a theory-of-mind task that did not involve a story. By comparing the brain areas across the studies, Mar identified a large

We internalize what a character experiences by mirroring *those feelings and actions.*

FROM "READING STORIES ACTIVATES NEURAL REPRESENTATIONS OF VISUAL AND MOTOR EXPERIENCES," BY NICOLE K. SPEER ET AL., IN *PSYCHOLOGICAL SCIENCE*, VOL. 20, NO. 8; AUGUST 2009

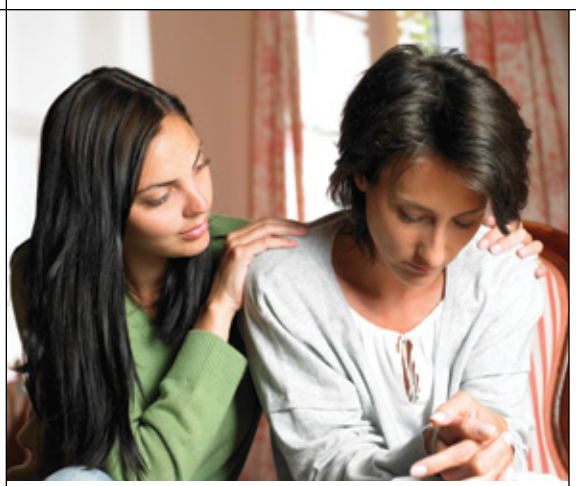
group of structures spanning disparate areas of the brain that all three tasks seemed to recruit. These regions, he concluded, make up a "core mentalizing network" that enables the understanding of others' mental events in life as well as in a story.

Such investigations support the idea that when we read fiction we put aside our own concerns and plans and adopt those of the story's protagonist. Doing so allows us to understand a story's events from the character's point of view. We do not actually experience the character's emotions—after all, the character is an abstraction. Rather we feel our own emotions in response to the yearnings, actions and circumstances the writer describes. The trajectory of these emotions keeps us turning the pages or glued to the screen. [For more on the power of stories, see "The Secrets of Storytelling: Why We Love a Good Yarn," by Jeremy Hsu; Scientific American Mind, August/September 2008.]

Changing Personality

The brain's emotional responses to good literature do more than forge a connection with a nonexistent personality—they can even alter the reader's sense of self. In a 2009 study Peterson and I, along with Toronto psychologists Maja Djikic and Sara Zoeterman, randomly assigned 166 people to read either the short story by Anton Chekhov entitled "The Lady with the Little Dog" or a version of it that Djikic rewrote in the style of a nonfiction report. In the story, a banker named Gomov meets a young woman, Anna, at the Russian seaside resort of Yalta as she is walking her dog. The two begin an affair. After they go home to their spouses, to their surprise, the affair refuses to fade in their minds. Gomov and Anna meet from time to time and long to be united, but the story ends without resolution. Djikic's version, written as a report from a divorce court, contained exactly the same information and was the same length and level of reading difficulty. Readers judged it to be just as interesting as Chekhov's story, though not as artistic.

Before and after reading the texts, the participants took a personality test that measured the Big Five traits and rated the intensity with which they felt 10 different emotions—sadness, anxiety, happiness, and so on. As compared with those who read the report, those who read the story underwent small but measurable personality changes. Participants changed in different ways: some became more or less open to experience, for example, whereas others were more or less agreeable after exposure to the story. The degree of personality change paralleled the amount of emotional change a participant experienced during reading. As with all good literature, Chekhov's story prompted people to think and feel in new ways, but the particular feelings and thoughts it evoked depended on the reader.



Reading fiction builds a person's capacity for empathy and improves her ability to understand the mental states of others. A "core mentalizing network" in the brain enables the latter skill.

Only the story version seemed to enable readers to empathize with Gomov and Anna. The properties of fictional narrative invite identification with characters in ways that nonfiction usually does not. Great art, it seems, may prompt perturbations in the usually stable structure of personality. Although the personality changes we found were probably temporary, as people spend more time reading fiction they may become, say, more open and perceptive about others in general.

We may often think of stories as diversions. But how we engage with them involves the same mental processes that enable us to interact with others in daily life. Entering the simulated worlds of stories and engaging with the minds of their characters changes us. Because of their power over the mind, stories may be useful in the development of interpersonal skills and relationships among children and adolescents. And no matter your age, curling up comfortably with a novel in an armchair may do your mind—and social life—a bit of good. **M**

(Further Reading)

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- **Exploring the Link between Reading Fiction and Empathy: Ruling out Individual Differences and Examining Outcomes.** Raymond Mar, Keith Oatley and Jordan Peterson in *Communications: The European Journal of Communication Research,* Vol. 34, No. 4, pages 407–428; December 2009.
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- **The Neural Bases of Social Cognition and Story Comprehension.** Raymond Mar in *Annual Review of Psychology,* Vol. 62, pages 103–134; 2011.
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- The psychology of fiction: **www.onfiction.ca**

GHISLAIN & MARIE DAVID DE LOSSY *Aurora Photos*

Grief without Tears

People are not always devastated by a death and should be allowed to recover in their own way

BY HAL ARKOWITZ AND SCOTT O. LILIENFELD

Grief comes in many guises. At this funeral party for a 65-year-old nurse from Ghana, women donning festive dresses greet the family of the deceased.

COURTESY OF HAL ARKOWITZ (*Arkowitz*); COURTESY OF SCOTT O. LILIENFELD (*Lilienfeld*); ROBERT STOLARIK *Redux Pictures* (*funeral*)

VIRTUALLY all of us experience the loss of a loved one at some point in our life. So it is surprising that the serious study of grief is not much more than 30 years old. Yet in that time, we have made significant discoveries that have deepened our understanding of this phenomenon—and challenged widely held assumptions.

In this column, we confront two common misconceptions about grief. The first is that the bereaved inevitably experience intense symptoms of distress and depression. The second is that unless those who have experienced the death of a loved one "work through" their feelings about the loss, they will surely experience delayed grief reactions, in which strong emotions may be triggered by events unrelated to the loss, even long after it occurred. As we will show, neither belief holds up well to scientific scrutiny.

Bouncing Back

Most people believe that distress and depression almost always follow the death of someone close, according to psychologists Camille B. Wortman of Stony Brook University and Kathrin Boerner of Mount Sinai School of Medicine. Symptoms of distress include yearning for the deceased, feeling that life has lost its meaning, having anxiety about the future and experiencing shock at the loss. Depression involves feeling sad and self-critical, having suicidal thoughts, lacking energy, and undergoing disturbed appetite and sleep.

To examine this belief, several groups of investigators tracked bereaved people, mostly widows and widowers, for up to five years. Results revealed that between 26 and 65 percent had *no* significant symptoms in the initial years after their loss; only 9 to 41 percent did. (The variability results partly from differences in how the symptoms were measured.) And the depression of some may be chronic rather than a reaction to the death.

Psychologist George A. Bonanno of Columbia University and his colleagues

examined this possibility and other questions in a prospective study published in 2002. They followed about 1,500 elderly married individuals over several years. During that time 205 subjects lost a spouse, after which the investigators continued to track them for 18 months. Surprisingly, about half of the bereaved spouses experienced no significant depression either before or after the loss. Nor did they display serious distress, although some did feel sad for a short time. Eight percent of the participants were depressed *before* losing his or her partner—and stayed that way. For about 10 percent—individuals who had reported being very unhappy in their marriage—the death actually brought relief from preexisting depression.

The spouse's death did precipitate depression in 27 percent. Of these individuals, a substantial proportion (about 11 percent of the total) started improving after six months and became symptom-free within 18 months. The rest of that subgroup did not get better—but even so, more than 70 percent of the study's participants neither developed depression nor became more depressed as a result of their spouse's demise. (The small number of remaining subjects fit various other patterns.) These results tell a clear story, at least where an elderly partner is concerned: most people are resilient and do not become seriously depressed or distressed when someone close to them dies.

Working It Out

In her 1980 book *The Courage to Grieve,* social worker Judy Tatelbaum wrote that after the death of a loved one "we must thoroughly experience all the feelings evoked by our loss," and if we don't "problems and symptoms of unsuccessful grief" will occur. The idea that people need to work through grief originated with Sigmund Freud and is still pervasive. It usually includes expressing feelings about the loss, reviewing memories about the deceased and finding meaning in the loss. According to this view, those who do not explore their emotions will suffer the consequences later.

Yet grief work may be unnecessary for the large proportion of people who do not become significantly distraught after a loss. And when researchers have tested the common grief-work techniques of writing or talking about the death, some have found small benefits for the procedures, but most have not. In addition, the jury is still out on grief counseling, in which professionals or peers try to facilitate the working-through process. Results from two quantitative reviews of the efficacy of such therapy found no significant gains from it, and a third found just a modest positive effect. One caveat: the benefits might be slightly greater than these studies indicate because most of the subjects were recruited by the researchers, and these individuals may be less in need of counseling than those who seek help.

Finally, two teams of researchers followed bereaved persons, including spouses, adult children and parents, for up to five years after their loss and found little or no evidence of a delayed grief reaction. When such reactions have been found, they occur only in a very small percentage of the bereaved. Thus, the overall risk of reexperiencing a flood of negative emotions appears to be quite minimal.

Given that most people who have experienced the death of a loved one show few signs of distress or depression, many bereaved individuals may need no particular advice or help. The few who experience intense and lasting despair may benefit from interventions, although traditional grief counseling may not be the best choice. Instead people might consider seeking empirically supported psychotherapies for depression [see "The Best Medicine?" by Hal Arkowitz and Scott O. Lilienfeld; Scientific American Mind, October/November 2007].

That said, our conclusions are based largely on studies of Caucasian American widows and widowers. We cannot say for sure that they extend to people of all ages, ethnicities and genders. In addition, reactions to a loss may depend on a person's relationship to the deceased—be it a parent, sibling or child—as well as whether the death was sudden, violent or drawn out. The consequences of these varying perspectives and circumstances have yet to be carefully explored.

Nevertheless, we can confidently say that just as people live their lives in vastly different ways, they cope with the death of others in disparate ways, too. Despite what some pop-psychology gurus tell us, grief is not a one-size-fits-all experience. **M**

> Researchers have found little or no evidence for **delayed grief reactions** among bereaved individuals.

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

Send suggestions for column topics to editors@SciAmMind.com

(Further Reading)

- **Beyond the Myths of Coping with Loss: Prevailing Assumptions versus Scientific Evidence.** Camille B. Wortman and Kathrin Boerner in *Foundations of Health Psychology.* Edited by Howard S. Friedman and Roxane Cohen Silver. Oxford University Press, 2007.
- **The Other Side of Sadness: What the New Science of Bereavement Tells Us about Life after Loss.** George A. Bonanno. Basic Books, 2009.

On the Trail of the Orchid Child

One genetic variant leads to the best and worst outcomes in kids

BY WRAY HERBERT

MATT MENDELSON (*Herbert*); BARBARA KOSOFF (*children and flowers*)

SCIENTIFIC PAPERS tend to be loaded with statistics and jargon, so it is always a delightful surprise to stumble on a nugget of poetry in an otherwise technical report. So it was with a 2005 paper in the journal *Development and Psychopathology,* drily entitled "Biological Sensitivity to Context," which looked at kids' susceptibility to their family environment. The authors of the research paper, human development specialists Bruce J. Ellis of the University of Arizona and W. Thomas Boyce of the University of California, Berkeley, borrowed a Swedish idiom to name a startling new concept in genetics and child development: *orkidebarn*.

Orkidebarn means "orchid child," and it stands in contrast to *maskrosbarn,* or "dandelion child." As Ellis and Boyce explained in their paper, dandelion children seem to have the capacity to survive—even thrive—in whatever circumstances they encounter. They are psychologically resilient. Orchid children, in contrast, are highly sensitive to their environment, especially to the quality of parenting they receive. If neglected, orchid children promptly wither—but if they are nurtured, they not only survive but flourish. In the authors' poetic language, an orchid child becomes "a flower of unusual delicacy and beauty."

Sensitive Souls

Inside the small world of scientists who study genetics and child development, the notion of the orchid child was stunning. The idea of resilient children was hardly new, nor was the related idea that some kids are especially vulnerable to the stresses of their world. What was novel was the idea that some of the vul-

nerable, highly reactive children—the orchid children—had the capacity for both withering and thriving. They appeared to be extremely sensitive to home and family life, for better or worse. Is it possible, scientists wondered, that genes underlie this double-edged childhood sensitivity?

Ellis and Boyce's paper launched a search both for those genes and for the risk pathways that might lead to bad outcomes such as delinquency, substance abuse and mental illness. Most of the work initially focused on the genes that behavioral geneticists call the "usual suspects"—and it paid off. Studies soon showed that genes linked to particular enzymes or brain chemical receptors, if combined with family stress or maltreatment, can lead to a slew of behavioral problems or mood disorders. These links have now been verified again and again, and scientists are searching for additional genes that might play a role in this exquisite childhood sensitivity.

But where to look? If one is looking for genes that might be linked to unhappy lives, the genetics of heavy drinking is a place to start. That was the reasoning of behavioral geneticist Danielle M. Dick of Virginia Commonwealth University, who, with 13 other scientists from around the world, has been exploring a gene called *CHRM2*. *CHRM2* has already been implicated in alcohol dependence, which is in the same group of disruptive behaviors as childhood conduct disorders and antisocial behavior. What's more, the gene codes for a chemical receptor involved in many brain functions, such as learning and memory, so the gene might also be involved in behavioral disorders. Dick and her colleagues recently decided to test the idea.

The team of researchers took DNA samples from a group of more than 400 boys and girls who have been part of a larger child development study since before kindergarten and analyzed variations in their *CHRM2* gene. These kids did not have behavioral problems at the start; they were a representative sample from communities in three U.S. cities. The youngsters have been studied every year since kindergarten, and they were around age 17 at the time of this new study. The scientists collected information on the teenagers' misbehavior—delinquency, aggression, drug abuse, and so on—from both the mothers and the kids themselves. They also asked the teens how much their parents knew about their lives—such as their whereabouts, who they hung out with, what they did with their time, and how they spent their money. They wanted to get a general idea of how closely these kids were monitored by their parents in their daily comings and goings as a way of measuring parental nurturing, indifference or neglect.

Withering or Thriving

As reported in the April *Psychological Science*, the genetic and behavioral data are consistent with the orchid child model of susceptibility. That is, certain variations in the children's *CHRM2* gene appear to interact with parental negligence to produce the most undesirable teenage behavior. But the nature of that interaction is what is most important: the genetic variant that combined with lousy parenting to produce the worst aggression and delinquency also combined with the most attentive parenting to produce the *best* teenage outcomes. Put another way, the kids who ran the highest risk of developing bad behaviors in bad homes were least likely to struggle when living in healthy, nurturing homes.

Although the scientists studied parental monitoring or awareness, this measure is most likely a proxy for a teenager's environment more generally. That is, adolescents who scored low on parental involvement are probably more likely to live in unsafe neighborhoods and to hang out with friends who tend to get into trouble. Some kids—the dandelion children—might do okay in such a world, but these stresses may be enough to tank the genetically sensitive orchid children.

If *CHRM2* does turn out to be an orchid child gene, some earlier findings might now begin to make sense. For example, the gene has also been linked to serious depression in some studies and to cognitive ability in others. But the gene does not appear to code for these outcomes directly, nor do all these outcomes necessarily show up in all genetically at-risk teenagers. Indeed, *CHRM2* may not be a gene "for" anything—other than the tendency to follow life's fortunes or misfortunes. M

> The kids at the highest risk of developing **bad behaviors** in bad homes were the least likely to fail in nurturing homes.

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.

(Further Reading)

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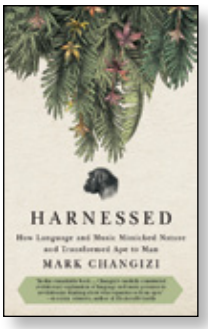
- ***CHRM2*, Parental Monitoring, and Adolescent Externalizing Behavior: Evidence for Gene-Environment Interaction.** Danielle M. Dick et al. in *Psychological Science,* Vol. 22, No. 4, pages 481–489; April 2011.

books

MAKING NOISE

Harnessed: How Language and Music Mimicked Nature and Transformed Ape to Man

by Mark Changizi. BenBella Books, 2011 ($16.95)



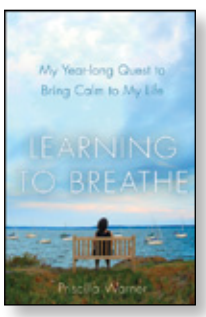
Once upon a time, humans could not hold conversations or sing songs together. Now we chatter incessantly, not only with speech but also through text messages, tweets and status updates. How we transformed into the highly social species we are today remains the subject of many theories.

Two competing hypotheses center on whether our capacity for language is an innate skill that grew stronger through natural selection or whether we lacked any such ability and instead trained our brains to collect new information using objects and sounds in our environment. In his new book *Harnessed,* Mark Changizi stakes out the middle ground: cultural—not natural—selection explains our language ability.

Generating controversial theories is not new to this evolutionary neurobiologist. In his previous book, *The Vision Revolution,* he argued that writing evolved from the shapes our ancestors saw in nature. In *Harnessed* he extends that logic to claim that the most common sounds we hear in nature—of objects making contact or sliding across one another, such as the patter of footsteps or the hiss of a hunted animal dragged across the ground by a predator—occur more frequently and consistently in human language than chance would allow. People evolved auditory systems that process natural noises efficiently, although we are capable of producing a range of sounds broader than those found in nature. Changizi proposes that our culture—that is, language and music, among other artifacts—evolved around, or "harnessed," the sounds we already process best.

The tricky part, however, is that Changizi's theory is almost impossible to test. The bulk of his evidence consists of correlations he observes between sounds in nature and those in language, and he devotes much of the book to acoustical analyses of the two. But the examples he cites are just that—correlations, not causes. In addition, Changizi never explains why other apes, which heard the same sounds as early humans, did not develop language.

Nevertheless, the idea of culture as an actor in the evolutionary process, rather than its by-product, provides an interesting way to frame the question of how we learned to communicate through language. —*Frank Bures*



ATTACK PANIC

Learning to Breathe: My Year-long Quest to Bring Calm to My Life

by Priscilla Warner. Free Press (Simon & Schuster), 2011 ($23)

For the millions of people who suffer from panic disorder, every passing minute brings them closer to the next attack.

Writer Priscilla Warner has lived on edge her whole life. Crippled by panic attacks for four decades and tired of relying on drugs to help manage them, she finally decided to take control of her illness. Her new book, *Learning to Breathe,* details her journey as she seeks to break her addiction to clonazepam, a drug for relieving panic attacks, to achieve a monklike state of calm.

The book follows Warner as she struggles to transform her fast-paced, pill-popping New York lifestyle to a more peaceful existence filled with meditative retreats, Buddhist teachings, Kabbalah rituals and sessions with psychotherapists. She also seeks the counsel of friends, relatives and gracious strangers to help her cope with her unresolved problems—a difficult upbringing and her mother's decline as she battles Alzheimer's disease, among other troubles.

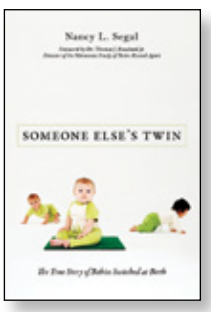
Warner is exhaustive in describing every meditation, teaching and treatment she discovers, each of which seems to help her in some way. Although the reader wishes Warner all the best, the narrative quickly becomes predictable and monotonous. When she participates in a brain-imaging study to track her progress, she misses a chance to create a powerful moment: she skims over the neural underpinnings of her recovery and instead simply marvels at how colorful her MRI scan is. Many recent brain studies have shown connections between meditation and improved cognitive function, including better concentration and mood regulation. Had she explored the neuroscience, she could have tracked the physical effects different treatments had on her brain to determine which ones were truly working and how.

That said, Warner's success warrants respect. Despite its flaws, the book describes a courageous woman transformed from an anxiety-stricken, neurotic victim to a calm and balanced figure. Her story is a message of hope for those who, like Warner, wonder if they will ever find such a thing as life without panic. —*Samantha Murphy*

MISTAKEN IDENTITY

Someone Else's Twin: The True Story of Babies Switched at Birth

by Nancy L. Segal. Prometheus Books, 2011 ($25)



In 1973 identical twins Delia and Begoña were accidentally separated in the Canary Islands hospital where they were born. Begoña went home with her parents and an unrelated baby, Beatriz, who was raised as her twin. Meanwhile, 50 miles away, Beatriz's parents brought up Delia as their daughter.

Fast-forward 28 years, when a local store clerk mistakes Begoña for Delia. Convinced the two are twins, she arranges a meeting. The meeting fundamentally alters the sisters' sense of identity—as well as that of their parents and siblings.

In *Someone Else's Twin,* Nancy L. Segal delves into this extraordinary, tragic case to tackle both the scientific significance of identical twins and the humanistic questions they spark about identity. Segal, a fraternal twin and psychologist who directs the Twin Studies Center at California State University, Fullerton, gained access to the women in exchange for acting as an expert witness in their lawsuit against the Canary Islands

Roundup: **Train the Brain**

Two books and a podcast series explore how we can improve our minds.

Music may inspire us to dance, but can the right melody help improve our mental health? Yes, it can, according to Don Campbell, author of *The Mozart Effect,* and Alex Doman, an expert in music therapy. In **Healing at the Speed of Sound** (Hudson Street Press, 2011), the authors explore how we can use different soundtracks and even silence to tap into our brain's creative side and to make us more efficient, relaxed and healthy.

The constant buzz of your cell phone or the compulsion to check e-mail may make it difficult for you to find a peaceful moment to think and reflect. In **The Thinking Life** (St. Martin's Press, 2011), P. M. Forni, civility expert and professor at Johns Hopkins University, emphasizes the importance of serious reflection for improving our creativity, attention and problem-solving skills and offers suggestions for ways to focus our scattered brains.

We all know how stressful a breakup can be, but we still do not understand the brain chemistry behind this natural response or how best to dampen it. In a free podcast from the series **NeuroScene,** Harvard University professor Sara Lazar discusses her neuroimaging studies, which demonstrate that meditation increases the concentration of gray matter in specific areas of the brain thought to be associated with stress, memory and empathy. Tune in to previous and upcoming podcasts to learn how the brain copes with stress and panic. *—Victoria Stern*

ISTOCKPHOTO

Health Services. Her position is clear: "Suddenly finding a twin in adulthood revises everything about one's personal identity—who one is and who one should have been."

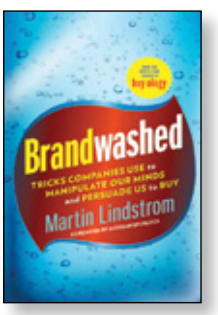
She bolsters her position with findings from the 20-year Minnesota Study of Twins Reared Apart, in which Segal was an investigator, and other research. Regardless of how they are raised, identical twins are more alike than fraternal twins in height, weight, health, intelligence, athleticism, social attitudes and job satisfaction, underscoring the influence of genes on these qualities. Indeed, the relationship between identical twins is so unique that a Spanish physician contended that Delia and Begoña's separation violated their "fundamental right to personal identity."

Segal describes how Beatriz, too, suffered a devastating loss when the switch was discovered. The twins' parents also were shattered. Research on maternity certainty—a mother's confidence that a child is her own—has shown that new mothers perform better than chance when trying to recognize their newborns within a couple of hours using senses other than sight; fathers are better at picking out their babies visually. Failing to spot a switch or to act forcefully on that instinct only adds to the grief of the new reality. "Saying your child has been switched," the father of a switched pair tells Segal, "is like saying she's been killed." *—Jordan Lite*

POWER PLAYS

Brandwashed: Tricks Companies Use to Manipulate Our Minds and Persuade Us to Buy

by Martin Lindstrom. Crown Business, 2011 ($25)



In the produce aisles of grocery stores, prices are often written in chalk on small slate signs, a subtle tactic to suggest the fruits and vegetables are farm fresh. Yet most of these signs are not handwritten; they are machine-made and cast in indelible ink. And the apple? It is far from fresh, picked some 14 months earlier.

Although we may think we make purchases for sensible reasons, Martin Lindstrom argues in *Brandwashed* that the choices we make are anything but rational. In reality, advertising companies convince us to buy things by exploiting our hopes and fears. For instance, the body spray manufacturer Axe planted marketers in bars across the country recently to watch unsuspecting twentysomething males try to pick up girls. In doing so, Axe advertisers stumbled on a niche market: the "Insecure Novice"—the guy who, despite his best efforts, left the bar alone every night. If the story sounds familiar, that is because it was echoed in the company's popular "nerd-sprays-Axe, nerd-gets-girl" commercials, a campaign that helped to solidify the company's multimillion-dollar hold on the personal hygiene market.

And did you recently "Like" a product on Facebook? Advertisers also mine publicly shared information to develop powerful marketing tools. Personalized ads, with your seal of approval, may now appear on your friends' profile pages.

Brandwashed's downside is that Lindstrom, a world-renowned advertising guru, overvalues neuromarketing functional MRI studies. For example, he writes that he once advised a luxury automaker to design a car that was "sex on four wheels" because experiments have shown that a man's brain was activated in the same areas when viewing a picture of a horse with a large penis as when ogling an image of his dream car. Many neuroscientists would argue that simply observing that the brain engages similar regions during an fMRI scan does not mean our underlying thoughts and desires are the same.

By Lindstrom's account, even when you know advertisers' tricks, avoiding them can be difficult, and he admits being fooled on occasion by sneaky advertising maneuvers. Which may make you wonder: In a free market, exactly how free are we, anyway? *—Brian Mossop*

askthe**Brains**

How does our brain learn new information?

—**David Graybill**, New York City

Heidi Johansen-Berg, *a neuroscientist at the University of Oxford, responds:*

THE BRAIN is an enormously complex network of billions of neurons connected by more than 90,000 miles of fibers—long enough to traverse Russia's coastline four times. This intricate architecture allows us to absorb information quickly and efficiently. Learning mainly takes place at synapses, the junctions between neurons where information is relayed. A synapse's performance changes when we learn something new, obeying the principle that "cells that fire together, wire together."

To understand this concept, first imagine trying to remember the name of a new colleague, a tall, bearded man we'll call Joe. Your brain needs to form an association between a complex visual image and a name, which are encoded by different groups of neurons in various parts of your brain. Every time you are introduced to Joe, these sets of neurons fire simultaneously, strengthening the synaptic pathway that connects them. Next time you spot a tall, bearded man coming down the corridor, you will easily greet Joe because the visual image will be strongly linked with his name.

Many different events can increase a synapse's strength when we learn new skills. The process that we understand best is called long-term potentiation, in which repeatedly stimulating two neurons at the same time fortifies the link between them. After a strong connection is established between these neurons, stimulating the first neuron will more likely excite the second.

In addition to making existing synapses more robust, learning causes the brain to grow larger. Optical imaging allows researchers to visualize this growth in animals. For instance, when a rat learns a difficult skill, such as reaching through a hole for a pellet of food, within minutes new protrusions, called dendritic spines, grow on the synapses in its motor cortex, the region that allows animals to plan and execute movements.

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Although we cannot see these tiny details in living human brains, we can use brain scanners to visualize larger changes that happen as we learn over longer periods. Learning to juggle, for example, increases the size of parts of the brain involved in looking at and reaching for moving objects and strengthens the pathways that connect these regions.

Are we biologically inclined to couple for life?

—**Chelsea Brennan**, Minneapolis

Jeannine Callea Stamatakis, *who is an instructor at several colleges in the San Francisco Bay Area, responds:*

"TILL DEATH DO US PART" is a compelling idea, but with the divorce rate exceeding 50 percent, many people would very likely agree that humans have a biological impulse to be nonmonogamous. One popular theory suggests that the brain is wired to seek out as many partners as possible, a behavior observed in nature. Chimpanzees, for instance, live in promiscuous social groups where males copulate with many females, and vice versa.

But other animals are known to bond for life. Instead of living in a pack like coyotes or wolves, red foxes form a monogamous pair, share their parental and hunting duties equally, and remain a unit until death.

For humans, monogamy is not biologically ordained. According to evolutionary psychologist David M. Buss of the University of Texas at Austin, humans are in general innately inclined toward nonmonogamy. But, Buss argues, promiscuity is not a universal phenomenon; lifelong relationships can and do work for many people.

So what distinguishes the couples that go the distance? According to several studies, a range of nonbiological factors can help pinpoint which pairings are built to last—those who communicate openly, respect each other, share common interests and maintain a close friendship even when the intense attraction wanes.

John Gottman, a psychologist emeritus at the University of Washington, developed a model to predict which newlywed couples will remain married and which will divorce, a method that he claims is 90 percent accurate. He found that most divorces happen at critical points after a couple unites. The first period occurs after seven years, when pairs tend to feel the strain of their relationship (does the *Seven Year Itch* ring a bell?). After 20 years, couples may encounter "empty nest syndrome"—a lonely feeling that can take over when children leave home, causing a rift in the marital bond.

A couples' therapist recently shared with me one key question that he always asks his clients: "Tell me about your wedding day." An answer composed of positive memories is a good sign. A couple that instead begins talking about the rain and stress is also offering a telling clue. M

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

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Head Games

Match wits with the Mensa puzzlers

1 SENTENCE SNAKE

Find the coiled sentence hidden in the grid to complete the second line of verse, which will rhyme with the first. You can start at any letter, and the path can travel in any direction.

I TRIED TO SAVE FOR A RAINY DAY,

Y	A	I	A	R	B
W	A	N	H	U	E
K	N	A	T	T	H
A	H	S	W	A	S
B	E	T	D	E	H

2 USE YOUR NOGGIN

Change the first letter of each pair of words to make a new word, using the same letter for both words in the pair (pairs share the same line). Then write the pair's new beginning letter in the space between the two words. Make sure the letters reading down the middle column spell a sensible word. What is that word?

(Example: BROWN ___ BLOWN could be changed to CROWN ___ CLOWN.)

CLIP ___ GLIDE
PART ___ LOVE
LISLE ___ STILT
COUGH ___ HEADY
SHREW ___ RAILED

3 SCRAMBLE

The following 14 letters consist of one scrambled 13-letter word and one irrelevant letter put in to make it harder. What is the 13-letter word?

I R N E D L E F T I A A G B

4 TOOLING AROUND

At the hardware store, a hammer costs two thirds as much as a wrench, a three-piece screwdriver costs as much as a hammer and wrench together, and a roll of duct tape costs the price of the wrench minus the price of the hammer. If buying one of each costs $5.50, what is the price of each item?

5 FROM LOSS TO GAIN

Change LOSS to GAIN in 10 steps, changing one letter at a time and making a valid English word at each step.

LOSS

____
____
____
____
____
____
____
____
____

GAIN

6 PRICING RIGHT

$0.90 $1.20 $0.60 $0.60 ?

7 WHAT A GAS

Fuel prices are skyrocketing. In November my heating bill was $30 more than my October bill. In December I paid $20 more than in November, and in January I paid $60 more than in December. The total bill for the four months was $1,200. How much did I pay for fuel in October?

8 MEET YOUR MATCH

The following matchstick equation is incorrect. Make a correct equation by moving two matches.

Answers

1. BUT THE RAIN HAS WASHED THE BANK AWAY. (Start at the B in the upper right corner.)
2. SMART.
3. INDEFATIGABLE.
4. The hammer costs $1.00, the wrench $1.50, the screwdriver $2.50 and the duct tape 50 cents.
5. Here is one way to do it: LOSS, LOST, POST, PAST, PART, PARK, LARK, LARD, LAID, LAIN, GAIN.
6. 60 cents. (30 cents per vowel in the word.)
7. $252.50. (Add the additional $30 from November, $50 from December and $110 from January to get $190. Subtract $190 from $1,200 to get $1,010, which divided by four gives the base price of $252.50 per month.)
8. Here is one solution:

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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