THE OLYMPIC EDGE: WHAT SETS WINNERS APART? page 38

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THE FOLLIES OF ONLINE DATING

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HOW TO PREVENT ALZHEIMER'S

What research says about steps you can take right now

THE PARADOX OF EATING MEAT

TRICKS OUR EYES PLAY

NEARSIGHTED KIDS: AN EPIDEMIC

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COVER PHOTOGRAPH BY AARON GOODMAN, MAKEUP BY MARCELLO COSTA/REDKEN AMBASSADOR; THIS PAGE: AARON GOODMAN (*Wallis*)

Of Sound Mind and Body

When we chose 89-year-old Barbara Singer as the cover model for this issue, we were drawn to her lively, expressive face, the glint of humor and intelligence in her eyes. And yes, the cool glasses, too. Little did we know she was a perfect fit for our cover story, beginning on page 28, about how to keep Alzheimer's disease at bay.

The article was written by neurologist David A. Bennett, director of the Rush Alzheimer's Disease Center in Chicago. For nearly 25 years Bennett has overseen two major, longitudinal studies identifying factors that appear to offer a measure of protection from dementia—or at least slow its encroachment. The results, which reflect data from more than 1,350 brain autopsies—show that there are things all of us can do to stockpile "cognitive reserve," a surfeit of brainpower that, as Bennett writes, "[makes] our brain less vulnerable to the ravages of aging." These include acquiring more years of education, eating right, learning a foreign language, staying physically and socially active, and retaining a sense of purpose in life.

Singer does it all. She exercises, eats right and brims with purpose. Modeling and acting (recently in a Woody Allen project) is her third career; she had been an x-ray technician and photographer. Devoted to learning, she has taken philosophy classes and consultations at New York City's Aesthetic Realism Foundation for decades. She is also busy promoting the work of her late husband, photographer and poet Nat Herz. "I feel strong enough to keep going for at least another 10 years," Singer told me.

Elsewhere in this issue we explore another aspect of mental and physical staying power—the kind that leads to Olympic medals. In "The Right Stuff," starting on page 38, journalist Rachel Nuwer examines recent research on the mental and physical traits that separate the world's top athletes from the rest of us. For a related story on page 45, writer Bret Stetka interviewed sports psychologists to learn what kind of coaching best helps athletes keep their eyes on the prize.

Speaking of eyes, two stories deal with our remarkable sense of vision. Starting on page 56, you can feast your eyes—and confuse them—with an array of images and illusions designed to determine how our visual system makes sense of shape and shadow. They are the work of neurologist Chaipat Chunharas and neuroscientist Vilayanur S. Ramachandran, a member of *Mind*'s advisory board. And on page 62, journalist Diana Kwon explores the global epidemic of myopia that is predicted to leave half the world needing glasses by 2050. As always, I hope this issue will bring the astonishing power of the brain and senses into sharper focus.

Claudia Wallis
Managing Editor
MindEditors@sciam.com

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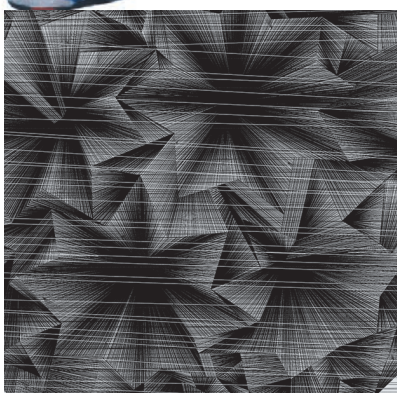

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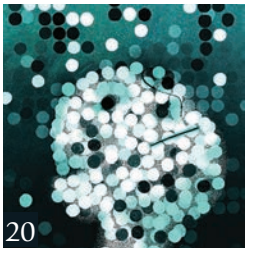

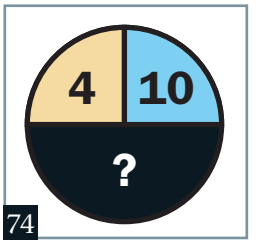

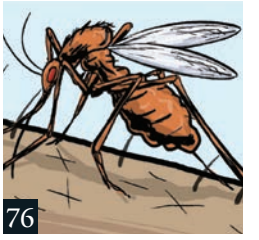

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WHAT ABOUT VEGETARIANS?

While reading "In Search of the Optimal Brain Diet," by Bret Stetka, I wondered if the studies cited considered vegetarian and vegan diets. As a vegetarian myself, I believe that I have become healthier by eliminating meat from my diet, but after reading this article, one might deduce that individuals who do not consume fish are more likely to experience mental illness at some point in life. If the optimal brain diet includes seafood, should vegetarians be concerned?

Mare Andon
via e-mail

STETKA REPLIES: *Based on the research, a vegetarian diet is certainly one of the healthiest options for the body. It just might not be the healthiest for the brain, at least for some people. Vegetarianism has been associated with conditions such as depression, anxiety and vitamin B_{12} deficiency, itself associated with developmental delay and a range of neurological problems. Furthermore, the Mediterranean diet, which includes plenty of fish, has been linked with a lower risk of depression and dementia.*

One way to counter the possible brain health shortcomings of a vegetarian diet is supplementation. Some psychiatrists recommend that vegetarians supplement with B_{12} and with omega-3 fatty acids derived from plants, but at least one study found that omega-3 fatty acids from seafood are incorporated into the brain far more efficiently than those from plant sources.

For herbivores who avoid meat for ethical reasons but who could be at risk for mental illness—or for those who just don't want to take any chances—shellfish could be an option. Given that bivalves such as mussels and oysters do not have a central nervous system, many experts believe they do not feel pain.

RESOURCES FOR FRAGILE X

I am extremely grateful for "The Carriers," by Anne Skomorowsky—an excellent and informative article on the fragile X premutation.

For those of us who are afflicted with fragile X–associated tremor/ataxia syndrome (FXTAS) and fragile X–associated primary ovarian insufficiency (FXPOI), Skomorowsky's article provides some relief because now we know that this syndrome is getting attention in the scientific world. Perhaps as a result, there will be a treatment someday.

Two Web sites have been launched for sufferers of FXTAS and primary ovarian failure (which can affect women with FXPOI) in the hopes of creating a sense of community for those who are afflicted with these conditions and for their families: www.fxtassupportgroup.org and www.pofus.org.

Please continue your superb coverage of fragile X.

J. W. Yanowitz
Seattle

I write to you as the executive officer of the Fragile X Association of Australia, a small, member-based nonprofit charity that provides support to individuals and families affected by fragile X–associated disorders in Australia.

We found "The Carriers" to be extremely well written and informative, and we would like to commend you for carrying an article on a topic that is critical to so many people and families around the world.

Our organization would also like to extend our congratulations to Anne Skomorowsky for making quite complex information about the fragile X

THE CARRIERS

A genetic anomaly—the fragile X premutation—puts millions of people at risk for infertility and a neurodegenerative disorder they have probably never heard of

By Anne Skomorowsky

premutation understandable and accessible in her article.

Wendy Bruce
Manly, New South Wales, Australia

SOCIAL MEDIA AND HEALTH

I'm curious about some other variables that might affect the health data gleaned from Google, Facebook and Twitter, as discussed in "Status Update: Stressed, Angry, at Risk?" by Johannes C. Eichstaedt.

The article states that certain negative words used online by people engaged in social media are representative of various health risks such as heart disease. I wonder if there have been any studies of how often these people engage in social media. Perhaps the "positive" people are online less than the "negative" ones, giving the former a better outlook on life and better overall health.

Laura Irwin
Vancouver, Wash.

SKEPTICAL OF THE SPECTRUM

What I'm most struck by after reading "The Invisible Girls," Maia Szalavitz's article on autism diagnoses in females, is how laughably we are stumbling through this whole terrain. Words matter. With some borderline cases, the stigma of a diagnosis may be worse than any benefit from classification.

"Autism spectrum disorder" has a negative connotation because "autism," at its most extreme, is a disadvantageous condition that handicaps one in society. Thus, to say one is on its spectrum is to say one is on a spectrum of disadvantage. And because, this article implies, autism's underlying qualities apparently manifest within all humans—and these manifestations come with such delicate shadings as to be easily muddled among all the other delicate shadings of the human condition—everyone can be put on this spectrum of disadvantage.

Take the example of psychopaths, as we commonly call individuals with an extreme lack of empathy. We all have varying degrees of empathy. Would you say that we all lie on a psychopathic spectrum? Would you say that Mother Teresa did? Perhaps you argue, "Well, she was closer to an extreme degree of empathy. Let's reverse the spectrum nomenclature for her. Instead of low on the psychopathic spectrum, we'll say she was high on the empathy spectrum." But if so, then where does your exceptionally successful businessperson, the CEO who must lay off 10,000 people in the morning and still sleep at night, lie? Compared with the average individual, would you say that person is "high on the psychopathic spectrum?"

Rather than putting people on this psychopathic spectrum, let's just say we know what a psychopath is: someone with so little empathy it is truly extremely disadvantageous. If a spectrum must be used, let's say that the CEOs have less empathy than the norm or maybe that they are lower on an emotional sensitivity scale. People can be low on that scale and still be good people. They can compensate by using cognitive abilities. Perhaps they can even do more good than someone with slightly greater empathy but much less cognitive skill. It would obviously be a disservice to label these people as being on the psychopathic spectrum.

Back to autism. Rather than putting everyone on a spectrum of disadvantage, let's invent a word for it without that connotation. Say, "focusivity"—a proclivity for a singular focus. Because not only are we doing a pretty poor job of diagnosing it, we are doing an even worse job of knowing whether or when being on the autism (or focusivity) spectrum is bad or good.

Alfred Winsor Brown V
Huntington Beach, Calif.

ADULTS LIKE FANTASY, TOO

"The Fantasy Advantage," by Deena Weisberg, was brilliant in talking about how fantasy-themed stories could produce better vocabulary and learning outcomes in children. Beyond children, it occurs to me there are increasing numbers of adults who regularly immerse themselves in the world of role-playing, simulation games, Japanese anime, and hybrids of live-action and computer-animated movies. I wonder if researchers could learn more about why fantasy is so beneficial to children by studying the common factors between fantasy-loving adults and kids. Why are certain individuals more inclined toward the imaginary?

Rowena Kong
via e-mail

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Head Lines

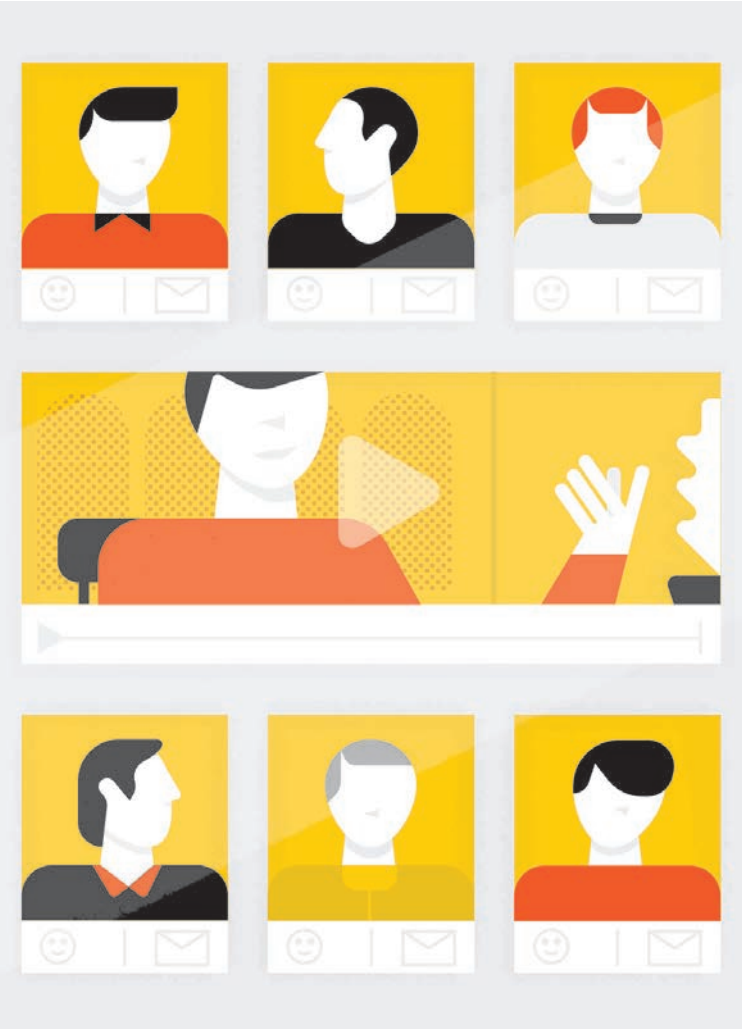
A USER'S GUIDE TO THE BRAIN

Science Hacks Digital Dating

FINDING LOVE ONLINE

Boost your odds of making a match with these new research-based insights: use videos for a more accurate first impression, skip the anonymous browsing option and swipe slowly.

ILLUSTRATIONS BY MATTHEW HOLLISTER



A Video Is Worth a Thousand Words

Photos make for skewed first impressions, but videos give the right clues

If you have ever chosen a profile picture for an online dating site, you have probably tried to pick a shot that gets across some of your key traits—energetic, friendly, silly, warm. Yet recent research suggests that the people who see your photograph are probably not accurately gauging your personality. A new study finds that a short video can leave a much more accurate first impression.

Researchers at the University of Texas at Austin put together a speed-dating pool of about 200 men and women. They also took photos of the participants, mimicking those found on online dating sites, and recorded short videos of the same individuals to see what kinds of first impressions people would form in each context. For each scenario, participants rated those they "met" on traits such as attractiveness, humor, intelligence and other qualities that we usually judge within seconds. The researchers presented their findings in January at the Society for Personality and Social Psychology meeting in San Diego.

Ratings from the three groups showed that individuals were more likely to agree on what another person was like if they met face-to-face or saw a video of that person. But when they had only a picture to go by, the raters used more of their own beliefs and schemas to make judgments. When someone describes a static image, "it tells me more about the viewer than it tells me about the person in the photograph," says senior researcher Paul Eastwick, an associate professor of psychology at U.T. Austin.

The reason we misjudge photos, the researchers say, is that the limited information contained in a photo puts us in an abstract mindset. We then draw on our past experience and expectations to fill in the blanks. A video, on the other hand, contains dynamic details that capture our attention and quickly reveal volumes about a person's personality—even if the clip is just a few seconds long. Someone's smile, voice and gestures, for example, provide instant clues about his or her agreeableness, trustworthiness and self-confidence.

Live impressions, of course, are the most powerful. So when you start warming up to a potential date online, Eastwick says, it is important to get to that meet-up at a coffee shop or bar so you can get a more authentic sense of the person. Meanwhile wily entrepreneurs are already creating dating apps based on videos, not photos.

—Knvul Sheikh

The Follies of Speed Swiping

Why patience pays when looking for love

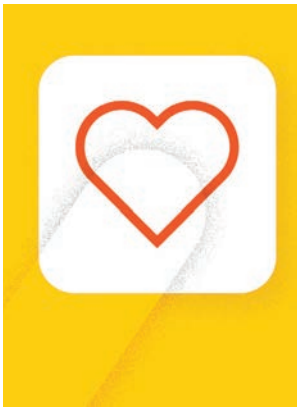
Ideally, any potential date deserves a fresh look, unaffected by what you thought of the last person you saw. But new research suggests that we may not be giving prospects a fair chance when we switch or swipe from one profile to another on dating apps and Web sites.

In a study described in March in *Scientific Reports,* female subjects saw men's faces on a screen for 300 milliseconds—about the length of a very short view on a dating app such as Tinder. After each face, they judged it attractive or not. The researchers found that faces were more likely to be judged attractive when they followed other attractive faces. Two factors caused this pattern: a response bias, in which one presses the same key as last time, and a perceptual effect mostly likely caused by the short interval allowed for processing the faces.

Previous studies have shown contrast effects, in which people in photographs look uglier when viewed next to portraits of attractive strangers. But in the new study, the exposure was so brief that an individual face was not fully processed, and thus it took on qualities of the previous face. Jessica Taubert, one of the lead authors of the paper and a researcher at the University of Sydney, advises online daters: "Be mindful that your brain has limited cortical resources." In other words, slow down!

In another new paper, in the *Journal of Experimental Social Psychology,* researchers asked whether contrast effects occur when judging personality. Participants viewed two dating profiles. When the first person came across as uncaring ("I get bored talking about feelings and stuff"), the second person, who was nice but unattractive, seemed much more appealing. In real profiles, people might not appear as blatantly callous as in this study, but other personality traits could be turnoffs that bias viewers' later decisions.

So whether on Tinder or OkCupid, it pays to clear your head and try to view each profile as a unique individual—before rushing on to the next one. —*Matthew Hutson*



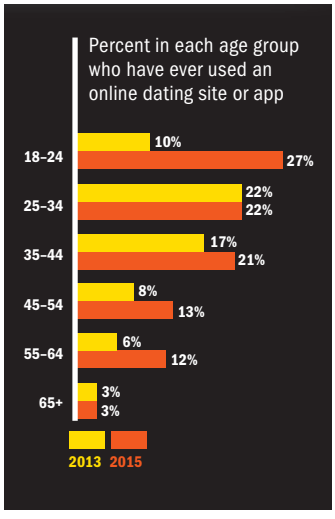
To Hide or Not to Hide

Anonymous browsing may backfire

Online dating provides opportunities we do not have in the real world, like scanning 100 potential sweethearts in an hour. But some of these advantages may actually be drawbacks. Anonymous browsing, for instance, allows users to look at people's profiles without the target knowing they got checked out—which can mean freedom from drawing unwanted messages. Yet it also erases any breadcrumbs that might lead to love. A paper published online in February in *Management Science* finds that on the whole, this feature backfires.

The researchers selected 100,000 users of a large online dating site and gave half of them the ability to browse anonymously, which usually costs extra. They became less inhibited and more likely to look at people of the same sex or a different race. "We thought the disinhibition would translate into more matches," says Jui Ramaprasad, a professor of information systems at McGill University and one of the paper's four authors. But women with this ability actually made fewer matches because they did not leave so-called weak signals of interest that might lead the other party to follow up. The simple notification that a particular person perused your profile is often enough to get a conversation started. Anonymous browsing did not affect men's matches as much, because the men were already uninhibited—they messaged individuals who interested them. Women, however, are less likely in general to make the first move and therefore depend more on sending weak signals to invite flirtation.

Further, what secret scanners lost in quantity they did not gain in quality. The average romantic appeal of their matches, as rated by other users, was no different from those of nonanonymous users. In the end, daters may be better off retaining the digital equivalent of exchanging furtive glances at a bar. —***Matthew Hutson***



Everybody's Doing It

A new Pew Research Center survey shows an increase from 2013 to 2015 in virtual dating for most age groups, especially among young millennials.

SOURCE: "15% OF AMERICAN ADULTS HAVE USED ONLINE DATING SITES OR MOBILE DATING APPS," BY AARON SMITH. PEW RESEARCH CENTER. PUBLISHED ONLINE FEBRUARY 11, 2016

Beyond "Mama" and "Dada"

Babies learn different types of words first depending on their native language

Financial Stress Hurts

A recent study links a shaky economic outlook and feelings of physical pain

Few things feel worse than not knowing when your next paycheck is coming. Economic insecurity has been shown to have a whole host of negative effects, including low self-esteem and impaired cognitive functioning. It turns out financial stress can also physically hurt, according to a paper published in February in *Psychological Science.*

GETTY IMAGES

Eileen Chou, a public policy professor at the University of Virginia, and her collaborators began by analyzing a data set of 33,720 U.S. households and found that those with higher levels of unemployment were more likely to purchase over-the-counter painkillers. Then, using a series of experiments, the team discovered that simply thinking about the prospect of financial insecurity was enough to increase pain. For example, people reported feeling almost double the amount of physical pain in their body after recalling a financially unstable time in their life as compared with those who thought about a secure period. In another experiment, university students who were primed to feel anxious about future employment prospects removed their hand from an ice bucket more quickly (showing less pain tolerance) than those who were not. The researchers also found that economic insecurity reduced people's sense of control, which, in turn, increased feelings of pain.

Chou and her colleagues suggest that because of this link between financial insecurity and decreased pain tolerance, the recent recession may have been a factor in fueling the prescription painkiller epidemic. Other experts are cautious about taking the findings that far. "I think the hypothesis [that financial stress causes pain] has a lot of merit, but it

Twila Tardif, a linguist at the University of Michigan, remembers the day she and her Mandarin-speaking babysitter watched as Tardif's 11-month-old daughter crawled over to a pen that had just fallen on the floor and pointed to it. "Pen!" Tardif told her daughter in Mandarin just as her sitter said, "Grab!" also in Mandarin. Then they looked at each other in puzzlement. Tardif realized that caregivers in different cultures might be influencing which words babies learn first.

Tardif's earlier work had shown that English-speaking children learn nouns first, almost exclusively, whereas Mandarin-speaking children's early spoken vocabulary has many more verbs than nouns. Babies' early comprehension follows the same pattern, but the difference is not as extreme.

In Tardif's most recent study (forthcoming), she followed 70 children learning English, Mandarin and Cantonese in Michigan, Beijing and Hong Kong from the time they were eight months old, before most of them spoke any words, to 30 months old, when most had a vocabulary of 500 to 700 words. By two and a half years most Mandarin-speaking children had reached a 50–50 balance of verbs to nouns. The English-speaking children had acquired about three times as many nouns as verbs.

"This pattern is probably an artifact of what babies hear in each language," Tardif says. Mandarin is a verb-focused language; a speaker can omit the subject of a sentence in many situations. Because Mandarin verbs are very regular and have few tense markings, it is easy to pick out patterns compared with the free-for-all of English irregular verbs. In addition, English-speaking parents tend to use vague, one-size-fits-all verbs as they emphasize nouns: cars, trucks, buses, bicycles and scooters all simply "go." Mandarin speakers do the opposite: they use catch-all nouns such as "vehicle" but describe action—driving, riding, sitting on, pushing—with very specific verbs. "As a native English speaker, my first instinct when a baby points is to label," Tardif says. Her babysitter, on the other hand, was a native Mandarin speaker, whose instinct was to name the action she thought the child was trying to achieve.

"Language is always a simplification of the world, and different languages simplify in different directions," Tardif says. "The big question is, If you talk about the world in different ways, does that mean you see the world differently?" —*Meredith Knight*

would be helpful to see additional rigorous evidence in a real-world environment," says Heather Schofield, an economist at the University of Pennsylvania who was not involved in the study. Given that stress in general is well known to increase feelings of pain, further research is needed to disentangle financial anxiety from other sources of pressure. —*Diana Kwon*

Friends Can Help Alleviate Money Woes

Financial stress may not only ratchet up physical pain, it may also amplify emotional pain. Studies have shown that making less money intensifies the pain felt from difficult life events, such as divorce, poor health and loneliness. But money troubles do not mean a person is doomed to suffer. A 2014 study found that social support can help protect against both the psychological and physical pain associated with financial stress.

—*Victoria Stern*

PHARMA WATCH

Do Proton-Pump Inhibitors Cause Dementia?

A recent study suggests—but does not prove—a link

THE CLAIM

Routine use of proton-pump inhibitors (PPIs)—drugs such as Nexium and Prilosec, used to treat heartburn, gastroesophageal reflux disease or peptic ulcers—may cause or accelerate dementia in elderly individuals.

THE FACTS

A direct link between PPI use and dementia remains unproved, but the association is plausible and warrants further investigation given the debilitating nature of dementia and lack of effective treatments for it.

THE DETAILS

As was widely reported in the media in February, German researchers discovered a possible link between PPI use and dementia. The team at the German Center for Neurodegenerative Diseases and elsewhere analyzed health insurance claims records for tens of thousands of elderly individuals, obtained from a large provider of mandatory national health insurance in Germany. They scrutinized filled prescriptions and disease diagnoses for 73,679 individuals who were aged 75 years or older when the study began in 2004. The group included 2,950 participants who were routinely prescribed PPIs and 70,729 who had not used such drugs.

During the course of seven years, 29,510 participants developed some form of cognitive decline, ranging from unspecified dementia to Alzheimer's disease. After adjusting for age, sex, potentially related conditions such as stroke or depression, and use of other prescription drugs, the team found that dementia diagnoses were more common in individuals with regular PPI prescriptions. On average, participants who filled a prescription for a PPI at least once every three months were more than 40 percent more likely to develop dementia than their PPI-free counterparts, according to the paper published online in February in *JAMA Neurology*.

The results are potentially worrisome considering the number of elderly individuals who take PPIs (recent studies estimate more than one quarter of U.S. nursing home residents use them) and the devastating, difficult-to-treat effects of dementia, says University of Pittsburgh epidemiology researcher Lewis Kuller, who was not involved in the study. In a related editorial in the same issue, Kuller estimated that thousands of otherwise avoidable dementia cases could occur in Germany, assuming the risk reported in the study is accurate, even if only 3 percent of the country's elderly use PPIs.

THE CAVEATS

It is tricky to prove or disprove the proposed PPI-dementia link using an observational study. For example, the researchers were not privy to information that may have offered an alternative explanation for individuals' cognitive deterioration, including genetic risk for Alzheimer's, explains lead investigator Britta Haenisch. People with other risk factors for dementia such as smoking or drinking may also be more likely to use PPIs—and such lifestyle factors were not part of the data. Nor was the team able to adjust for education, which can affect dementia diagnoses.

Haenisch and her colleagues addressed some of these issues in a smaller 2015 study that closely tracked 3,327 individuals, which found an almost 40 percent increase in dementia risk in elderly PPI users. Coupled with earlier studies that show a jump in levels of beta-amyloid protein, a telltale marker of Alzheimer's, in the brains of PPI-treated mice, Kuller says we cannot brush off findings from the latest paper.

"We don't know the cause [of dementia], we don't really understand any specific treatments, it causes a lot of disability, and we have a drug that's very widely used," Kuller says. "So you have to be more conservative than you would normally be." That might mean not only planning more targeted studies but also being cautious about overprescribing the drugs to older patients.

—*Andrea Anderson*

How PPIs Might Affect the Brain

PPIs reduce stomach acidity by dialing down the activity of an enzyme that shuttles charged ions through tiny gates—the so-called proton pumps—on the surface of cells lining the stomach. Experts posit that because at least some PPIs have been shown to cross the blood-brain barrier, they may have unanticipated effects on similar enzymes in the brain. Neural support cells called microglia rely on acid-containing organelles to degrade unwanted proteins; inhibiting acid production could impair the cells' ability to break up the protein tangles that are thought to be related to dementia.

Other enzymes related to beta-amyloid proteins may also be affected by the drugs in the brain. Given these plausible pathways, Haenisch explains, the drugs may inadvertently contribute to unhealthy protein accumulation. Studies of PPI-treated mice have confirmed that their brains contain higher levels of beta-amyloid proteins. And Haenisch points out another, simpler connection: PPI use has been linked to lower vitamin B_{12} availability, which itself has been implicated in cognitive decline.

—*A.A.*

Body Odor Is Less Offensive from "One of Us"

Feelings of affiliation reduce disgust

It's no secret that when abroad, travelers often find local residents' body odor particularly noxious. Now a study published in March in the *Proceedings of the National Academy of Sciences USA* shows that the degree of disgust we find in others' sweat may depend on whether we are thinking of them as part of our social group or as outsiders.

The team—led by Stephen D. Reicher, a psychologist at the University of St. Andrews (and a member of *Mind*'s advisory board)—asked 45 female University of Sussex students to hold and smell a sweaty T-shirt bearing the logo of another university and report how disgusting they found it on a scale of 1 to 7. They subtly primed the students to think of themselves as members of different groups by telling them different versions of the study's purported goals. In some cases, the researchers said they were measuring how well students could detect pheromones—activating the study subjects' feelings of affiliation with all other students, including the implied owner of the sweaty T-shirt. Other times the researchers said they were testing the detection ability of Sussex students, priming the study participants to think of the non-Sussex tee as having belonged to a member of a rival group. As a control condition, the researchers said they were looking at individual ability.

The students were considerably less disgusted when they thought the T-shirt's owner was in their group (a student at any university) compared with a different group (a student at a rival university) or when they were not thinking of groups at all. The researchers concluded that regarding someone as an "other" does not necessarily increase revulsion, but the idea that he or she is "one of us" may decrease it.

In a second experiment, 90 male and female St. Andrews students handled sweaty T-shirts with either a St. Andrews logo, that of a rival university or no logo. The researchers noted a similar effect: when the T-shirt seemed to be of their own group, the students moved less quickly across the room to a hand sanitizer station and used fewer pumps.

Scientists have linked disgust to an evolutionary instinct to avoid pathogens—from rotting meat or fouled water, for example. It also may keep us wary of strangers who could harbor unfamiliar germs. The new study adds an element to previous work confirming that people are remarkably tolerant of bad odors and even waste products when dealing with loved ones, says Jolanda Jetten, a psychologist at the University of Queensland in Australia, who was not involved in the study. "It shows that even something as basic as smell is regulated by group processes." *—Jordana Cepelewicz*

BUT DID THEY DO IT ON PURPOSE?

In non-Western societies, intent matters less when judging wrongdoing

It is no secret that morals vary from one culture to another. Behaviors that are acceptable in one society may bring condemnation in another. In spite of these differences, certain universals seem self-evident. Intent, for example, weighs into moral judgments: If a transgression is an accident, we often hand out a reduced punishment. Similarly, if the offender had a legitimate reason to do what he or she did, we take that into account, too.

Now, for the first time, a team of anthropologists has made a detailed cross-cultural study of the degree to which different societies consider intent and mitigating circumstances when forming moral judgments. The study, published in April in the *Proceedings of the National Academy of Sciences USA,* examined the judgments of more than 300 people in eight traditional, nonindustrial societies and two Western societies. Although intent and mitigating circumstances were relevant in all cases, the amount of emphasis placed on them varied widely.

In all societies, the most severe transgressions draw the harshest judgments, but cultures differ on whether or not intent is weighed heavily in such crimes. One scenario, for example, asked respondents to imagine that someone had poisoned a communal well, harming dozens of villagers. In many nonindustrial societies, this was seen as the most severe wrongdoing—and yet intent seemed to matter very little. The very act of poisoning the well "was judged to be so bad that, whether it was on purpose or accidental, it 'maxed out' the badness judgments," explains lead author H. Clark Barrett of the University of California, Los Angeles. "They accepted that it was accidental but said it's your responsibility to be vigilant in cases that cause that degree of harm."

The findings also suggest that people in industrial societies are more likely in general than those in traditional societies to consider intent. This, Barrett says, may reflect the fact that people raised in the West are immersed in complex sets of rules; judges, juries and law books are just the tip of the moral iceberg. "In small-scale societies, judgment may be equally sophisticated, but it isn't codified in these elaborate systems," he notes. "In some of these societies, people argue about moral matters for just as long as they do in any court in the U.S."

The authors suggest this line of work could help us navigate cultural disagreements over wrongdoing. Jesse Prinz, a philosopher at the City University of New York, agrees. We may be tempted to see our own moral opinions as superior—but that is an illusion of perspective, he says, adding that this kind of cross-cultural research can be a useful "exercise in humility." *—Dan Falk*

GETTY IMAGES (*rugby players*); ©ISTOCK.COM (*scales* and *pills*)

How a Messy Kitchen Might Ruin Your Diet

In a chaotic environment, people who do not feel in control tend to overeat

Unwashed pots and pans tower precariously in the sink. Last week's mail is strewn across the countertop, and a TV blares from the next room over. According to a study published in February in *Environment and Behavior,* this kind of chaotic environment can be enough to make someone overeat, given a certain mindset.

"We knew environmental factors influence behavior, and we knew the influence of stress on overeating in general," points outs Lenny Vartanian, a psychologist at the University of New South Wales in Australia and the study's lead author. "But nobody had connected those to say: here's an experience that lots of people actually encounter. What impact does [a disordered kitchen] have?"

To answer this question, the researchers set up two kitchens: one was cluttered and noisy, the other tidy and quiet. They then instructed 98 female undergraduates to complete a writing assignment while in one of the kitchens. Some of the volunteers wrote about a time they felt particularly out of control; others wrote about a time they felt in control. They were then provided with cookies, crackers and carrots and told they could eat as much as they wanted.

Among the participants who wrote about a time they felt out of control, those in the chaotic kitchen consumed twice as many calories from cookies as did those in the organized kitchen. Subjects in the messy kitchen who had thought about being in control, however, ate less than people in the other groups. "The in-control mindset buffered against the negative impact of the environment," Vartanian says. He and his team hope to eventually find ways to induce that powerful feeling of control in people in the real world, where kids, busy schedules and the messy business of life can make it tough to keep the kitchen tidy.

—Jordana Cepelewicz

The Gender of Names

A name's sound can convey masculine or feminine traits

One of language's great strengths is its flexibility—words can mean anything we want them to. But not all vocabulary is arbitrary. And according to a paper published in April in the *Journal of Personality and Social Psychology,* certain types of names are more likely to be given to boys versus girls, based merely on properties of their sound.

For decades researchers have discussed the role of sound symbolism, in which the sound of a word carries meaning regardless of its definition. The most famous example is the *bouba/kiki* effect: people across cultures and ages associate the made-up word *bouba* with round objects and *kiki* with spiky ones. As another example, the open volume in the mouth when pronouncing vowels expresses size; think of how big an event is evoked by *splosh* versus *splish.* To explore sound symbolism, Michael Slepian, the new paper's lead author and a researcher at Columbia Business School, says he wanted to "look to a place where people give new names to things all the time: other people." He and his collaborator at Columbia, Adam Galinsky, also wondered if sounds could convey social information.

In one study, the researchers analyzed 270 million recorded baby names in the U.S. from 1937 to 2013. They found that boys were more likely than girls to receive names beginning with "hard" (voiced) phonemes, which vibrate the vocal cords, such as the A in Adam and the B in Brian. Names starting with "soft" (unvoiced) phonemes, such as the F in Fiona or the H in Heather, were more often assigned to girls than to boys.

In several online experiments, the researchers also showed that people in both the U.S. and India perceived voiced names—whether real or invented, boys' names or girls'—as "harder" than unvoiced ones and thus more masculine. The sound-gender association was strongest in those who most highly endorsed the stereotype of men as tough and women as tender.

Slepian suggests that parents choosing baby names might use this information to play into gender norms—or to buck them.

—Matthew Hutson

The First Sound Matters

If a name's initial phoneme is "voiced," meaning it vibrates the vocal cords, it tends to be judged as "harder" and more masculine. Unvoiced phonemes, formed purely with the tongue and lips, tend to be judged as "softer" and more feminine. Here are some typical—and atypical!—examples:

VOICED	UNVOICED
ADAM	CAROL
BARBARA	CHARLES
DAVID	FELICIA
EDWARD	HOPE
GREGORY	KATHARINE
GERALD	PATRICK
IAN	PHOEBE
JESSICA	QUEENIE
LUKE	SARAH
MICHAEL	SHARON
NICHOLAS	TINA
OWEN	THEO
ROBERT	
ULYSSES	
VINCENT	
WILLIAM	
YVETTE	
ZACHARY	

Mouth movements influence word meaning in other ways, too: Words that move from the throat to the lips, such as "gap" and "cab," are more often associated with avoidance or pushing away. Words that move inward, however, such as "pick" and "big," tend to suggest approachability.

DONNA DAY Getty Images

How to Be a Better *patient*

I just turned 40, and no matter how well I take care of myself, I'm going to be seeing doctors more often as I continue to age. First, there are the sundry screenings one starts to require in middle age, mammograms and colonoscopies and the like. Plus, the risk of common ills such as hypertension and high cholesterol (both of which run in my family) starts to inch up. But being a good patient can be hard, as I found out last year during an extended but—I realize now—fully preventable dental ordeal. Here's what health and psychology studies have to say about becoming better partners in our own health.

#1 Ask a ton of questions. Arguably one of the best ways to be a good patient is by following your prescribed treatment or prevention plan. It's a concept known as compliance in medical research, but psychologist Richard M. Ryan doesn't like the passive sound of that term. "If you understand the rationale behind a doctor's recommendation, then you're more likely to embrace it and autonomously engage in a treatment," says Ryan, one of the founders of self-determination theory, which posits that internal sources of motivation are stronger than external rewards or threats. Ryan and his colleagues at the University of Rochester have found that people who ask the most questions about a recommended treatment are also the ones most likely to follow it—and achieve the best health outcomes. "Practitioners are pressed for time, and the medical system often doesn't actively encourage people to express their concerns, but you need to participate as a full partner in your treatment," Ryan says. If your doctor is not supportive of that, it's time to find a new one, he says.

#2 Automate your health habits. Only about half of us Americans manage to take our medications correctly and consistently, research has shown. We're even worse at following behavioral prescriptions such as losing weight, quitting smoking or, in my case, flossing every day. It took four very long, painful deep-cleaning sessions with a dental hygienist and some equally painful discussions with the dentist herself for me to finally grasp that the inflammation in my gums was serious, and if I didn't do my part, I was going to pay for it dearly. Making the choice to take even simple proactive steps throughout the day requires the exertion of willpower and self-control—two resources that we have in limited supply, according to a long-standing psychological theory. The more routine you can make your health habits, the less willpower they will take and the easier it will be to maintain them. Ryan suggests giving yourself environmental cues to further ease the way: "If you have medicine to take, put it in a spot you'll see it every morning. Or set an alarm to remind you."

#3 Go ahead and consult Dr. Google. Yes, the Internet is chock-full of unsubstantiated—even idiotic—health information. But there are plenty of reliable sites, such as those maintained by national medical associations and health systems (think www.cancer.org or www.mayoclinic.org). We do need to remember, though, that even when the information we find online is solid, it's not contextualized, says physician Suzanne Koven, a primary care internist at Massachusetts General Hospital. "I have enormous respect for patients' autonomy and understanding of their own bodies, and to some extent doctors are working with patients in a collaboration," she says. "But to pretend that both parties are bringing the identical degree of information to the table is disingenuous. Once in a while somebody will come in determined that they need an MRI to rule out such and such or this drug to treat such and such, and I'll have to say, 'Whoa, slow down, let's talk about you and your symptoms.'" Bottom line: As long as you use the Internet to self-educate rather than self-*diagnose,* a little online research can be a good thing.

#4 Don't lie. "So, are you flossing?" That was the question I came to dread at last year's many dental appointments. It was embarrassing to admit that, despite the work being put in by the hygienist and the interventions recommended by my dentist, I simply wasn't doing *my* part. But doctors can't diagnose or treat you optimally if you don't tell the truth, and thank goodness I did. My dentist gave me a three-month "last chance" of sorts to clean up my act—and then she promised (threatened?) to refer me to a gum specialist and, possibly, an oral surgeon. I realized then that I'd been relying on the medical pros to "fix" my health issue rather than partnering with them, so I made a commitment to change my routine. My husband brushes our two young daughters' teeth every night, and I started using that moment as a cue to do my own oral care. And guess whose gums are mostly in the pink again? Yep, this (better than before) patient's. —*Sunny Sea Gold*

MAGOZ (*illustration*): PAUL PANTAZESCU © *iStock.com* (*globe*)

FUTURE FOCUS

Tomorrow's Prosthetic Hand

Recent breakthroughs in technology could mean a fully functional artificial hand may be on the horizon

Touching Textures

Modern prostheses can provide amputees with a wide variety of motor functions, but they cannot give patients back their sense of touch. Until now, that is. In a collaborative effort, researchers at the Swiss Federal Institute of Technology in Lausanne and the Sant'Anna School of Advanced Studies in Pisa, Italy, developed a bionic fingertip that allowed an amputee to distinguish between smooth and rough textures with 96 percent accuracy. The fingertip is composed of an electrical sensor coated in a polymer, which translates surface coarseness into current pulses relayed to a nerve in the arm. The setup may even alleviate "phantom limb" pain, a common ordeal among amputees. Phantom hands are often perceived as being constantly clenched and painful, but the amputee in this experiment said he felt as though his phantom hand was feeling the surface, rather than remaining clenched. *—Jessica Schmerler*

A Realistic Replacement

Advances in 3-D printing have allowed scientists to build complex biomimetic hands, with plastic bones and ligaments that mirror every point of articulation in a natural human hand. As laboratory-grown human tissues are becoming more robust and viable, researchers hope that one day such biomimetic hands will serve as scaffolds over which the organic tissue of a real hand can be grown. University of Washington researcher Emanuel Todorov, who developed the hand pictured here with Zhe Xu of Yale University, says that using 3-D-printed plastic parts minimizes the possibility of rejection—a common problem with hand transplants—while cutting costs to a fraction of those associated with similar articulated prostheses. Because such models would look and act just like human hands, they also stand to have an easier learning curve for users. Not only will they operate like normal hands, 3-D printing also means each one could be customized to its user. *—Ian Chant*

Freeing the Fingers

Earlier this year an amputee was able to move individual fingers on his prosthetic arm with a 64 percent success rate, a Johns Hopkins University team reported in the *Journal of Neural Engineering*. The accomplishment is a major improvement over past experiments, which had only succeeded in moving combinations of fingers. The patient's brain signals were decoded by an electrocorticographic (ECoG) implant that can cover a large area of the brain, taking in and translating information from many groups of neurons and providing more stable readings than have been achieved through other methods. Even better, the signals controlling the prosthesis are intuitive, letting the patient operate the prosthetic hand without long training sessions. *—I.C.*

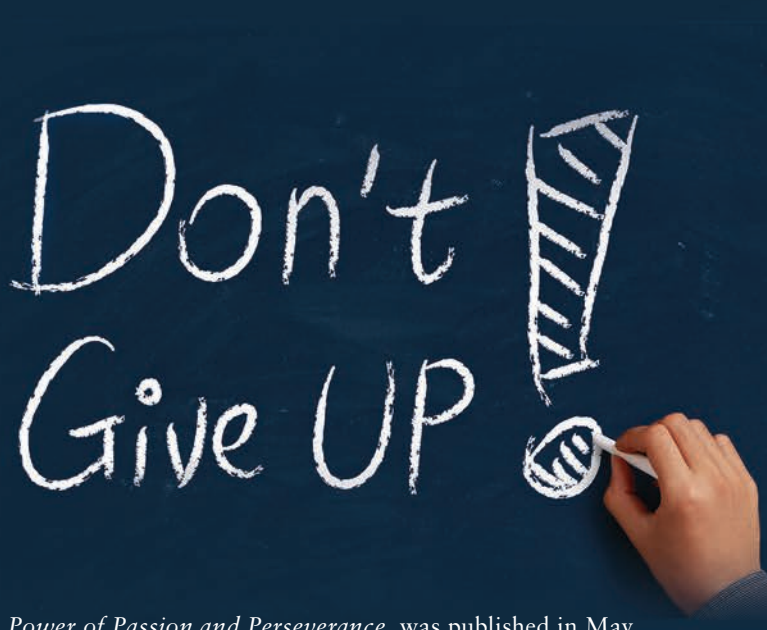
A Better Connection

Today's prosthesis users have to rely on visual cues to know whether they are touching or gripping something with their artificial hands. Now an improved "nerve cuff" allows for the sensation of tactile pressure to be communicated directly to the median, ulnar and radial nerves in the arm at the site of amputation. In a recent study, researchers at Case Western Reserve University and the Louis Stokes Cleveland VA Medical Center challenged blindfolded users to determine whether a wood block had been placed in their prosthetic hand and to locate and remove a magnetic block from a metal table. The subjects were able to tell when they were holding a block nearly 100 percent of the time. They were also more dexterous, locating the block faster, dropping it less often and making more natural corrections than in tests without the improved nerve-cuff feedback. The final piece of good news: subjects reported that with the better connection, they felt more confident and the prosthesis felt more like a part of their own body. *—I.C.*

THIS PAGE: EMANUEL TODOROV *University of Washington* AND ZHE XU *Yale University*; FROM "DESIGN OF A HIGHLY BIOMIMETIC ANTHROPOMORPHIC ROBOTIC HAND TOWARDS ARTIFICIAL LIMB REGENERATION," PRESENTED AT IEEE INTERNATIONAL CONFERENCE ON ROBOTICS AND AUTOMATION, STOCKHOLM, SWEDEN, MAY 16–21, 2016; OPPOSITE PAGE: CHRISTIAN CHAN *Getty Images*

The Great Grit Debate

Social and emotional skills are starting to be taught and tested in schools—but experts urge caution



Reading, writing, arithmetic—and grit and gratitude? A growing number of students and schools may start receiving grades for the two Gs, plus other so-called noncognitive traits, thanks to a recent update to the federal Elementary and Secondary Education Act. The new law requires states to include at least one nonacademic factor in their school evaluations. This year nine California school districts started including progress in social and emotional learning (SEL), as reported by students on questionnaires, in rating their schools. Other districts are considering following suit.

No one questions that building skills such as self-control, perseverance and conscientiousness can help children thrive. A 2011 meta-analysis of 213 of the best evidence-based SEL programs found that they led to significant improvements in social and emotional skills, behavior, attitudes and schoolwork. "It's what people want for their kids," notes developmental psychologist David S. Yeager of the University of Texas at Austin. But some researchers, like Yeager, who study noncognitive traits, are expressing real concern about the trend to test them and hold schools accountable.

For one thing, tests that measure qualities such as grit and persistence were designed for use in research settings and not as part of a high-stakes measure of student growth and school performance. "They weren't created for this purpose," warns Angela Duckworth, a psychologist at the University of Pennsylvania who developed a widely used eight- to 12-question test called the grit scale. Her research has shown that a high score on grit can predict success better than IQ in a variety of settings—from upping someone's chances of graduating from high school to winning the national spelling bee.

"You can't make high-stakes decisions based on measurements that can actually be wrong," cautions U.T. Austin researcher David S. Yeager.

That said, teaching things like grit via a lesson plan can be tricky. "The question of whether character can be learned is unambiguously yes," Yeager says, and kids absorb lessons from their social environment all the time, "but intentional efforts are far less successful than unintentional ones." Duckworth has experimented with using cartoons and videos to give middle school kids accurate information about deliberate practice, hard work and managing frustration. The results were modest: the program raised grades over just one marking period and only among low achievers. "I don't think grit is the best predictor of all kinds of achievement," says Duckworth, whose first book, *Grit: The Power of Passion and Perseverance,* was published in May.

Indeed, a recent study conducted by Kaili Rimfeld of King's College London and her colleagues found that grit had only a small effect on how well 16-year-old twins performed on standardized tests given in England and Wales. Rimfeld is skeptical of efforts by the U.S. and the U.K. departments of education to prioritize teaching noncognitive traits. Research has yet to prove that such "intervention programs" are helpful, she says.

Another serious problem with holding schools accountable for noncognitive learning is that progress can be hard to assess. Schools that provide strong social and emotional development tend to produce more self-critical students, who will rate themselves lower on SEL questionnaires. "It's just the humility that comes with expertise," Yeager explains. Last year Duckworth and her colleagues found evidence of this kind of reference bias in a study of more than 1,300 Boston eighth graders. Those at higher-performing charter schools deemed themselves less conscientious, less self-controlled and less gritty than lower-achieving peers at district public schools. When the scientists tracked individual classes over three years at two charter schools, they found that self-measures of noncognitive skills plummeted. The kids appeared to be holding themselves to a higher standard.

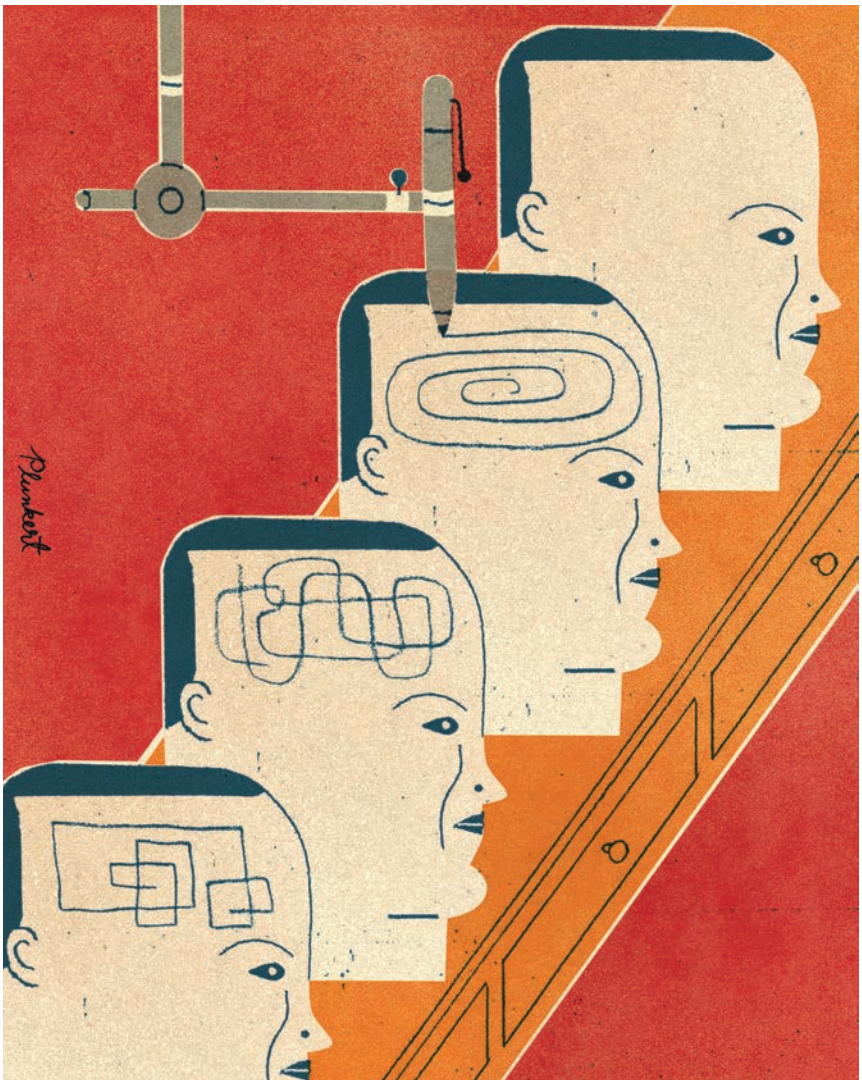
"You can't make high-stakes decisions based on measurements that can actually be wrong in the wrong direction," Yeager says. "You reward the people who are the worst and punish the people who are the best." A growing body of research shows how noncognitive abilities help children become happy, successful adults, Duckworth adds, but it is a misstep to then include them in school-accountability systems—now or maybe ever. "I just don't think carrots and sticks have been so effective in character development in the past," she says, "and I don't expect them to be all that helpful in the future." —*Kristin Ozelli*

RESEARCH

Sizing Up Psychology's Credibility Crisis

As more studies are called into question and researchers bicker over methodology, the field is showing a healthy willingness to face its problems

By John Horgan



DAVID PLUNKERT

Times are tough for young psychologists. This thought has been rattling around in my head lately because we just finished searching for a new psychology professor at the university where I teach. When I met candidates, I had to ask about their field's troubling replication—and credibility—crisis.

I felt as though I was pressing them on some sordid personal matter, like whether alcoholism runs in their families, but the topic is unavoidable. A key test of the validity of any scientific study is whether its results can be replicated by other scientists. Last year a group called the Open Science Collaboration reported in *Science* that more than half of 100 studies published in major psychology journals had failed that test, despite painstaking efforts to re-create the original experiments.

The disappointing news was widely covered, including by *Scientific American*. In a front-page story, the *New York Times* declared that the report "confirmed the worst fears of scientists who have long worried that [psychology] needed a strong correction. The vetted studies were considered part of the core knowledge by which scientists understand the dynamics of personality, relationships, learning and memory … the fact that so many of the studies were called into question could sow doubt in the scientific underpinnings of their work."

This past March the crisis made headlines again. A group of four prominent psychologists led by Daniel T. Gilbert of Harvard University claimed in *Science* that the 2015 Open Science Collaboration study was statistically flawed and did not prove its claim that "the reproducibility of psychological science is surprisingly low." "Indeed," Gilbert and his co-authors stated, "the data are consistent with the opposite conclusion, namely, that the reproducibility of psychological science is quite high."

In a rebuttal, 44 authors involved in the Open Science Collaboration countered that the "very optimistic assessment" of Gilbert's group "is limited by statistical misconceptions and by causal inferences from selectively interpreted, correlational data." The exchange, Bene-

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Send suggestions for column topics to **MindEditors@sciam.com**

dict Carey noted in the *New York Times,* "is likely to feed an already lively debate about how best to conduct and evaluate so-called replication projects of studies."

That's too cheery an assessment. The exchange reveals that psychologists cannot even agree on basic methods for arriving at "truth," whatever that is. As Katie M. Palmer pointed out in *Wired,* in an article headlined "Psychology Is in Crisis over Whether It's in Crisis," "two groups of very smart people are looking at the exact same data and coming to wildly different conclusions."

Meanwhile bad news keeps coming. A new study has raised doubts about the influential theory of "ego depletion," which holds that willpower is a finite resource that diminishes with use.

In a 1998 paper that has now been cited thousands of times, Roy F. Baumeister and three other psychologists presented experimental evidence for ego depletion. The theory has supposedly been corroborated by hundreds of other studies, and it underpins the 2011 best seller *Willpower: Rediscovering the Greatest Human Strength,* by Baumeister and journalist John Tierney.

A multicenter team led by Martin Hagger and Nikos Chatzisarantis, both at Curtin University, recently tested the ego-depletion hypothesis in a study involving 2,141 subjects. In an unedited version of the paper released early by the Association for Psychological Science, the team concludes that "if there is any [ego-depletion] effect, it is close to zero."

In a response, Baumeister and his colleague Kathleen D. Vohs dispute the methods of Hagger et al. but acknowledge that "this debacle shifts the burden of proof onto those of us who believe ego-depletion effects are genuine." They plan to conduct their own replication study next year.

In a *Slate* article with the apocalyptic headline "Everything Is Crumbling," journalist Daniel Engber notes that ego depletion is not "some crazy new idea, wobbling on a pile of flimsy data; it's a sturdy edifice of knowledge, built over many years from solid bricks.... If something this well established could fall apart, then what's next?" Good question, over which young psychologists are no doubt agonizing.

In the past, I've been hard on psychology, describing it as disturbingly faddish. Paradigms such as psychoanalysis and behaviorism never really die—they just go in and out of fashion. I like quoting linguist Noam Chomsky, who once said we will probably always learn more about ourselves from literature than from psychology. In that vein, I've argued that James Joyce's stream-of-consciousness masterpiece *Ulysses* gives us more insights into the working of our minds than any scientific study.

> BEHAVIORAL GENETICS AND PSYCHIATRY ARE MUCH LESS CREDIBLE THAN PSYCHOLOGY; STRING AND MULTIVERSE THEORISTS DON'T **EVEN HAVE EMPIRICAL RESULTS TO REPLICATE.**

But perhaps because of my recent meetings with aspiring young psychologists, I'm feeling oddly protective toward the field. In fact, in an attempt to hearten psychologists young and old, I'd like to make the following four points:

First, there's nothing new about psychology's credibility crisis. More than a century ago William James worried that the field he helped to create might never transcend its "confused and imperfect state." Howard Gardner argued in 1987 that "James's concerns have proved all too justified. Psychology has not added up to an integrated science, and it is unlikely ever to achieve that status."

Second, psychologists are still doing important, empirically sound work. Two who recently spoke at my school are Sheldon Solomon, co-creator of terror-management theory, which predicts how fear of death affects us, and Philip Tetlock, leader of a study on "superforecasters," ordinary people who do a better job than many so-called experts at predicting social phenomena.

Third, psychologists themselves have helped make us aware of how the quest for knowledge can go awry. Think of Daniel Kahneman's experiments on cognitive bias, on which he expounds in his blockbuster *Thinking Fast and Slow,* and Robert Trivers's research on self-deception, which he presents in *The Folly of Fools*. To help my students appreciate how we often see only what we're looking for, I show them the "invisible gorilla" video designed by Christopher Chabris and Daniel Simons.

Fourth, all scientific fields struggle with replication issues. Studies carried out over the past decade by statistician John Ioannidis have revealed that a large proportion of peer-reviewed claims turn out to be false. To my mind, behavioral genetics and psychiatry are much less credible than psychology, and string and multiverse theorists don't even have empirical results to replicate.

Psychology is arguably healthier than many other fields precisely because psychologists are energetically exposing its weaknesses and seeking ways to overcome them. I can't wait to chat about these issues next fall with my school's new psychology professor. **M**

MORE TO EXPLORE

- **Estimating the Reproducibility of Psychological Science.** Open Science Collaboration in *Science,* Vol. 349, page 943; August 28, 2015.
- **Comment on "Estimating the Reproducibility of Psychological Science."** Daniel T. Gilbert et al. in *Science,* Vol. 351, page 1037a; March 4, 2016.

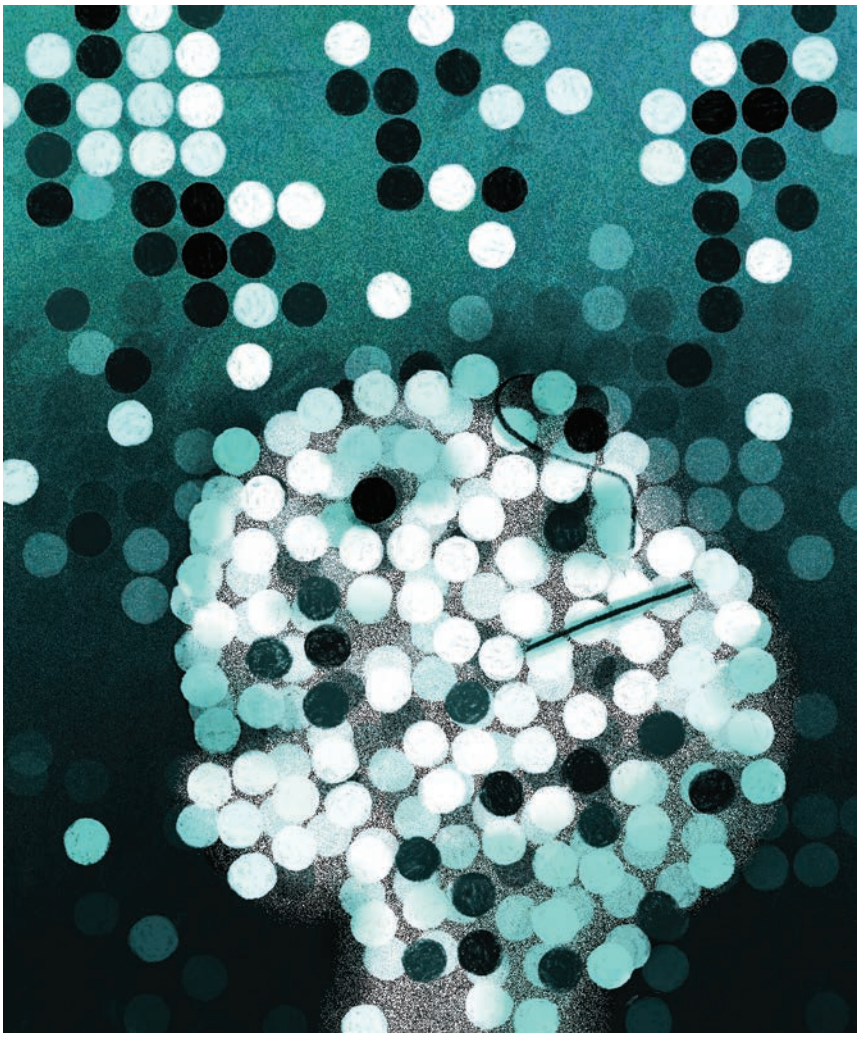
MACHINE LEARNING

How the Computer Beat the Go Player

As a leading go player falls to a machine, artificial intelligence takes a decisive step on the road to overtaking the natural variety

God moves the player,
he in turn, the piece.
But what god beyond
God begins the round
of dust and time and
sleep and agonies?

—Jorge Luis Borges, from "Chess," 1960



RICHIE POPE (*illustration*); SEAN McCABE (*Koch*)

The victory in March of the computer program AlphaGo over one of the world's top handful of go players marks the highest accomplishment to date for the burgeoning field of machine learning and intelligence. The computer beat Lee Sedol at go, a very old and traditional board game, at a highly publicized tournament in Seoul in a 4–1 rout. With this defeat, computers have bettered people in the last of the classical board games, this one known for its depth and simplicity. An era is over, and a new one has begun. The methods underlying AlphaGo, and its recent victory, have startling implications for the future of machine intelligence.

BY CHRISTOF KOCH

Christof Koch is president and chief scientific officer of the Allen Institute for Brain Science in Seattle. He serves on *Scientific American Mind*'s board of advisers.

Coming Out of Nowhere

The ascent of AlphaGo to the top of the go world has been stunning and quite distinct from the trajectory of machines playing chess. Over a period of more than a decade a dedicated team of hardware and software engineers hired by IBM built and programmed a special-purpose supercomputer named Deep Blue that did one thing and one thing only: play chess by evaluating 200 million board positions per second. In a widely expected development, the IBM team challenged then reigning world chess champion Garry Kasparov. In a six-game match played in 1996, Kasparov prevailed against Deep Blue by three wins, two draws and one loss but lost a year later in a historic rematch 3.5 to 2.5. (Scoring rules permit half points in the case of a draw.)

Chess is a classic game of strategy, similar to tic-tac-toe (noughts and crosses), checkers (draughts), Reversi (Othello), backgammon and go, in which players take turns placing or moving pieces. Unlike games where players see only their own cards and all discarded cards, players have full access to relevant information, with chance playing no role.

The rules of go are considerably simpler than those of chess. Black and White

sides each have access to a bowl of black and white stones, and each places one in turn on a 19-by-19 grid. Once placed, stones do not move. The intent of the game, originating in China more than 2,500 years ago, is to completely surround opposite stones. Such encircled stones are considered captured and are removed from the board. Out of this sheer simplicity, great beauty arises—complex battles between Black and White armies that span from the corners to the center of the board.

Strictly logical games, such as chess and go, can be characterized by how many possible positions can arise—a measure that defines their complexity. Depending on the phase of the game, players must pick one out of a small number of possible moves. A typical chess game may have 10^{120} possible moves, a huge number, considering there are only about 10^{80} atoms in the entire observable universe of galaxies, stars, planets, dogs, trees, people. But go's complexity is much bigger—at 10^{360} possible moves. This is a number beyond imagination and renders any thought of exhaustively evaluating all possible moves utterly unrealistic.

Given this virtually illimitable complexity, go is, much more than chess, about recognizing patterns that arise when clutches of stones surround empty spaces. Players perceive, consciously or not, relationships among groups of stones and talk about such seemingly fuzzy concepts as "light" and "heavy" shapes of stones and *aji,* meaning latent possibilities. Such concepts, however, are much harder to capture algorithmically than the formal rules of the game. Accordingly, computer go programs struggled compared with their chess counterparts, and none had ever beat a professional human under regular tournament conditions. Such an event was prognosticated to be at least a decade away.

And then AlphaGo burst into public consciousness via an article in one of the world's most respected science magazines, *Nature,* on January 28 of this year. Its software was developed by a 20-person team under erstwhile chess child prodigy and neuroscientist turned AI pioneer Demis Hassabis. (His London-based DeepMind Technologies was acquired in 2014 by Google.) Most intriguingly, the *Nature* article revealed that AlphaGo had played against the winner of the European go championship, Fan Hui, in October 2015 and won 5 to 0 without handicapping the human player, an unheard-of event. What is noteworthy is that AlphaGo's algorithms do not contain any genuinely novel insights or breakthroughs. The software combines good old-fashioned neural network algorithms and machine-learning techniques with superb software engineering running on powerful but fairly standard hardware—48 central processing units (CPUs) augmented by eight graphics processing units (GPUs) developed to render 3-D graphics for the gaming communities and exquisitely powered for running certain mathematical operations.

THE ALPHAGO SOFTWARE IMPROVED BY **PLAYING CEASELESSLY AGAINST ITSELF.**

At the heart of the computations are neural networks, distant descendants of neuronal circuits operating in biological brains. Multiple layers of artificial neurons process the input—the positions of stones on the 19-by-19 go board—and derive increasingly more abstract representations of various aspects of the game using something called convolutional networks. This same technology has made possible recent breakout performances in automatic image recognition—labeling, for example, all images posted to Facebook.

For any particular board position, two neural networks operate in tandem to optimize performance. A "policy network" reduces the breadth of the game by limiting the number of moves for a particular board position. It does so by learning to choose a small range of good moves for that position. A "value network" then estimates how likely a given board position will lead to a win without chasing down every node of the search tree. The policy network generates possible moves that the value network then judges on their likelihood to vanquish the opponent. These are processed using a technique called a Monte Carlo tree search, which can lead to optimal behavior even if only a tiny fraction of the complete game tree is explored.

A Monte Carlo tree search by itself was not good enough for these programs to compete at the world-class level. That required giving AlphaGo the ability to learn, initially by exposing it to previously played games of professional go players and subsequently by enabling the program to play millions of games against itself, continuously improving its performance in the process.

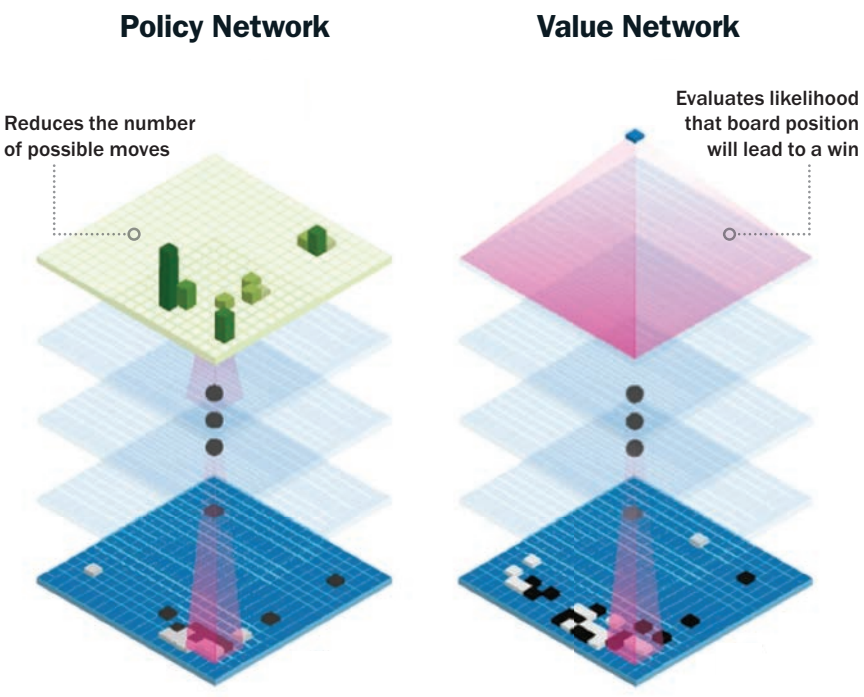
In the first stage, a 13-layer policy neural network started as a blank slate—with no prior exposure to go. It was then trained on 30 million board positions from 160,000 real-life games taken from a go database. That number represents far more games than any professional player would encounter in a lifetime. Each board position was paired with the actual move chosen by the player (which is why this technique is called supervised learning), and the connections among the simulated neurons in the network were adjusted using so-called deep-machine-learning techniques to make the network more likely to pick the better move the next time. The network was then tested by giving it a board position from a game it had previously never seen. It accurate-

ly, though far from perfectly, predicted the move that the professional player had picked.

In a second stage, the policy network trained itself using reinforcement learning. This technique is a lasting legacy of behaviorism—a school of thought dominant in psychology and biology in the first half of the 20th century. It professes the idea that organisms—from worms, flies and sea slugs to rats and people—learn by relating a particular action to specific stimuli that preceded it. As they do this over and over again, the organisms build up an association between stimulus and response. This can be done unconsciously using rote learning.

Reinforcement learning was implemented years ago in neural networks to mimic animal behavior and to train robots. DeepMind demonstrated this last year with a vengeance when networks were taught how to play 49 different Atari 2600 video games, including Video Pinball, Stargunner, Robot Tank, Road Runner, Pong, Space Invaders, Ms. Pac-Man, Alien and Montezuma's Revenge. (It was a sign of things to come: *atari* is a Japanese go term, signifying the imminent capture of one or more stones.)

Each time it played, the DeepMind network "saw" the same video-game screen, including the current score, that any human player would see. The network's output was a command to the joystick to move the cursor on the screen. Following the diktat of the programmer to maximize the game score, the algorithm did so and figured out the rules of the game over thousands and thousands of trials. It learned to move, to hit alien ships and to avoid being destroyed by them. And for some games, it achieved superhuman performance. The same powerful reinforcement-learning algorithm was deployed by AlphaGo, starting from the configuration of the policy networks after the supervised learning step.



The immensity of possible moves in the game of go requires that AlphaGo's designers endow the software with two separate networks. Using a humanlike evaluation process, a policy network (*left*) reduces the number of moves to be considered; the value network (*right*) predicts the probability of any one board position leading to a win.

In a third and final stage of training, the value network that estimates how likely a given board position will lead to a win is trained using 30 million self-generated positions that the policy network chose. It is this feature of self-play, impossible for humans to replicate (because it would require the player's mind to split itself into two independent "minds") that enables the algorithm to relentlessly improve.

A peculiarity of AlphaGo is that it will pick a strategy that maximizes the probability of winning regardless of by how much. For example, AlphaGo would prefer to win with 90 percent probability by two stones rather than with 85 percent probability by 50 stones. Few players would give up a slightly riskier chance to crush their opponent in favor of eking out a narrow but surer victory.

The end result is a program that performed better than any competitor and beat the go master Fan. Fan, however, is not among the top 300 world players, and among the upper echelons of players, differences in ability are so pronounced that even a lifetime of training would not enable Fan to beat somebody like Lee. Thus, based on the five publicly available games between AlphaGo and Fan, Lee confidently predicted that he would dominate AlphaGo, winning five games to nothing or, perhaps on a bad day, four games to one. What he did not reckon is that the program he was facing in Seoul was a vastly improved version of the one Fan had encountered six months earlier, optimized by relentless self-play.

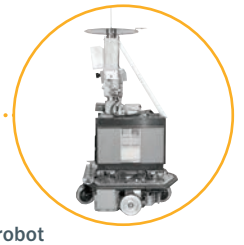
What's Next?

Deep Blue beating Kasparov represented a triumph of machine brawn over a single human brain. Its success was predicated on very fast processors, built for this purpose. Although its victory over Kasparov was unprecedented, the triumph did not lead to any practical application or to any spin-off. Indeed, IBM retired the machine soon thereafter.

FROM "MASTERING THE GAME OF GO WITH DEEP NEURAL NETWORKS AND TREE SEARCH," BY DAVID SILVER ET AL., IN *NATURE*, VOL. 529; JANUARY 28, 2016

A Chronology of Machine Smarts

The idea of an intelligent machine goes back to ancient Greek mythology. But the emergence of artificial intelligence as a scientific field in its own right arrived 60 years ago.



1969: Shakey the robot demonstrates cognitive and motor capabilities

1997: IBM's Deep Blue defeats chess champion Garry Kasparov

2011: IBM's Watson computer wins against human contestants at *Jeopardy!*

1956: An artificial-intelligence conference at Dartmouth College gives the field its name and a mission

1959: Marvin Minsky (*shown*) and John McCarthy set up M.I.T.'s AI Group

1987: Ernst Dickmanns and team demonstrates a Mercedes van that drives autonomously on an unopened stretch of autobahn

1994: World champion checkers player Marion Tinsley falls to a computer program called Chinook, developed at the University of Alberta

2013: Advances in neural networks help to attract billions of dollars in investment in AI from leading technology companies

2016: Google's AlphaGo beats top-ranked player Lee Se-dol

COURTESY OF MIT MUSEUM (*Minsky*); COURTESY OF SRI INTERNATIONAL (*Shakey*); GETTY IMAGES (*Kasparov and Lee*)

The same situation is not likely to occur for AlphaGo. The program runs on off-the-shelf processors. Giving it access to more computational power (by distributing it over a network of 1,200 CPUs and GPUs) only improved its performance marginally. The feature that makes the difference is AlphaGo's ability to split itself into two, playing against itself and continuously improving its overall performance. At this point it is not clear whether there is any limitation to how much AlphaGo can improve. (If only the same could be said of our old-fashioned brains.) It may be that this constitutes the beating heart of any intelligent system, the holy grail that researchers are pursuing—general artificial intelligence, rivaling human intelligence in its power and flexibility.

Most likely Hassabis's DeepMind team will contemplate designing more powerful programs, such as versions that can teach themselves go from scratch, without having to rely on the corpus of human games as examples, versions that learn chess, programs that simultaneously play checkers, chess and go at the world-class level, or ones that can tackle no-limit Texas hold'em poker or similar games of chance.

In a very commendable move, Hassabis and his colleagues described in exhaustive detail in their *Nature* article the algorithms and parameter settings used to generate AlphaGo. Their explanation of what was accomplished further accelerates the frenetic pace of AI research in academic and industrial laboratories around the globe. These types of reinforcement algorithms based on trial-and-error learning can be applied to myriad problems with sufficient labeled data, be they financial markets, medical diagnostics, robotics or warfare. A new era has begun with unknown but potentially monumental medium- and long-term consequences for employment patterns, population-wide surveillance, and growing political and economic inequity.

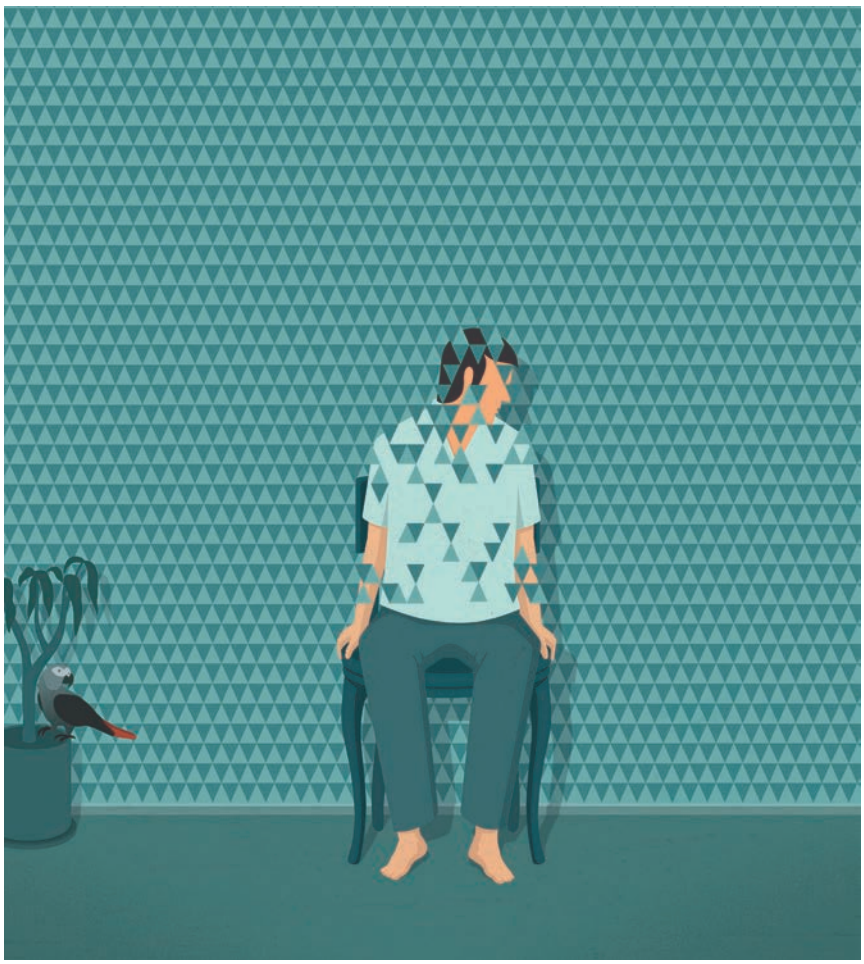
What of the effects of AlphaGo on the ancient game of go itself? Despite doomsayers, the rise of ubiquitous chess programs has revitalized chess, helping to train a generation of ever more powerful players. The same may well happen in the go community. After all, the fact that any car or motorcycle can speed faster than any runner did not eliminate running for fun. More people run marathons than ever.

Indeed, it could be argued that by removing the need to continually prove oneself to be the best, more humans may now enjoy the nature of this supremely aesthetic and intellectual game in its austere splendor for its own sake. In ancient China one of the four arts any cultivated scholar and gentleman was expected to master was the game of go. Just as a meaningful life must be lived and justified for its own intrinsic reasons, so should go be played for its intrinsic value—for the joy it gives. M

MORE TO EXPLORE

- **Mastering the Game of Go with Deep Neural Networks and Tree Search.** David Silver et al. in *Nature,* Vol. 529, pages 484–489; January 28, 2016.

Month after month, immobilized, Frank watched his bank account dwindle. Antidepressants helped his mood, but he was still barely functional, sitting home with his pet birds.



ILLUSTRATIONS BY STEPHAN SCHMITZ

Finding His Wings

Drugs lifted Frank's depression, but he had to find meaningful activity to relaunch his life

By David J. Hellerstein

Frank was stuck, his life going nowhere fast. It was not for a lack of effort: a well-educated man in his early 40s, he had tried several forms of psychotherapy to get back on track after impulsively quitting his high-paid but life-sucking commercial real estate job years earlier. But month after month, immobilized, Frank* watched his bank balance dwindle, and he became severely depressed. When I first saw him in my private office for a psychiatric evaluation a decade ago, Frank clearly met criteria for major depression, with low mood, poor sleep, feelings of hopelessness and suicidal thoughts.

DAVID J. HELLERSTEIN is a research psychiatrist at the New York State Psychiatric Institute and a professor of clinical psychiatry at the Columbia University College of Physicians and Surgeons. His practice focuses on the treatment of depression and anxiety disorders. He is author of *Heal Your Brain: How the New Neuropsychiatry Can Help You Go from Better to Well* (Johns Hopkins University Press, 2011).

FLAVORS OF THERAPY

Cognitive-behavioral therapy (CBT) is an evidence-based form of psychotherapy that is widely used to treat depression, phobias and other mental illnesses. It focuses on changing destructive patterns of thought and behavior. CBT comes in several flavors, some of which emphasize the cognitive and some the behavioral. Whereas pure cognitive therapy aims to help patients reframe their thinking, behavioral-activation therapy (used in this case study) seeks to increase the frequency of rewarding behaviors and activities to improve mood.

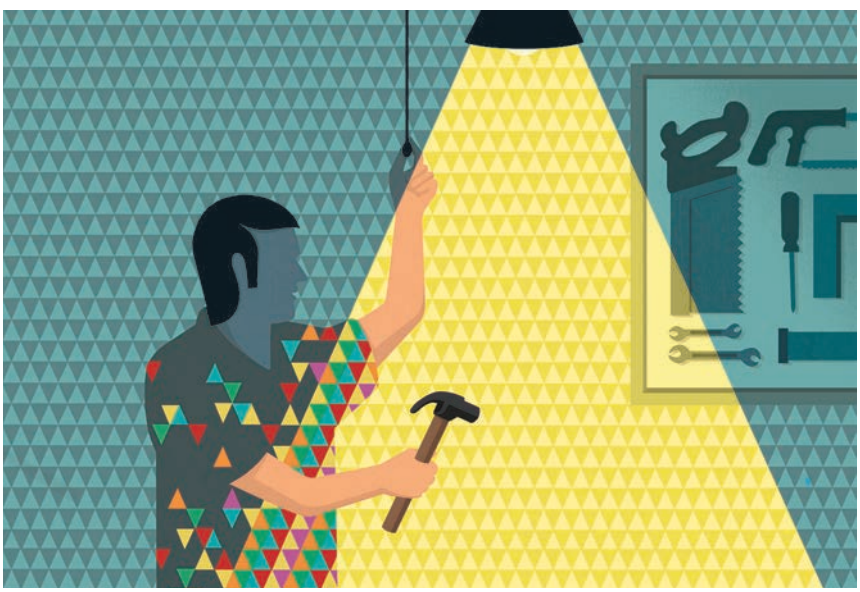
So I started Frank on an antidepressant medication, a selective serotonin reuptake inhibitor (SSRI) called sertraline. Within eight weeks his mood, sleep and other symptoms had improved. But he was still barely functional. For months he remained unemployed, sitting at home with his pet African grey parrots, which he adored, only leaving his apartment for doctors' appointments.

What to do? Frank had had years of traditional psychodynamic ("talk") therapy without much improvement: understanding the psychological origins of his inertia, however valuable, did not enable him to make meaningful changes. Similarly, cognitive therapy, which guides patients to reframe their thinking, had helped Frank to be somewhat less pessimistic about the possibility of changing his life but had not made a dent in his procrastination or avoidance. This pattern is not unusual in patients with depression: their symptoms improve with medication, but they still can't get off the couch.

Casting about for treatment options that might help Frank, I came across an intriguing approach: behavioral-activation (BA) therapy. A stripped-down form of cognitive-behavioral therapy (CBT), it focuses primarily on changing behaviors rather than thoughts. BA therapists ask patients to track their daily activities and encourage them to spend more time each day doing things they enjoy. The theory behind BA therapy for depression is that the disorder stems from decreased exposure to environmental rewards and that patients' negative thoughts and avoidance worsen in the absence of satisfying activities. This keeps them trapped in a cycle of misery and dysfunction.

One could describe BA as a Nike form of therapy, guided by the dictum "Just Do It." Simplistic though it may sound, it can be remarkably powerful. A 2006 randomized, controlled study of 241 depressed patients found, for instance, that BA was at least as effective as antidepressant medication—plus patients were more likely to stick with it—and that it was much more effective than cognitive therapy, with a 56 percent versus 36 percent success rate for those with severe symptoms. The challenge—and art—of BA is working closely with patients to get them to identify rewarding pursuits and then to change daily behavior even on a gradual basis, building on small improvements to make more meaningful changes. This can be quite difficult with patients, like Frank, who are psychologically stuck in the mud.

I referred Frank to Dr. V., whom I found through a local clinic specializing in CBT. "The BA approach doesn't entirely ignore thoughts," he told me when I called to make a referral. "For instance, one common thought among people who are depressed is, 'I need to feel better *before* I can make changes in my life.' Whereas as a BA therapist, I would say, 'Start making the changes *now*, and you will likely feel better.' "



**The patient's name and some identifying details have been altered to protect his privacy.*

As a therapist trained in psychodynamic therapy, which relies on words, many words, I had become accustomed to often waiting months, even years, for behavior to change, and the in-your-face BA approach, however appealing, was initially jarring to me. But things were desperate for Frank; something needed to be done.

"Okay, let's give it a try," I said.

Because Frank wanted—*needed*—to go back to work, Dr. V. initially focused on helping him to update his rusty job skills and begin networking for new opportunities. Frank did so, but progress was excruciatingly slow. Then one day, after six to eight weekly BA sessions, he told Dr. V. that after feeling a burst of energy, he had gone shopping for lumber and carpentry tools. Moreover, he had built a bench, something he had wanted to do for months. Dr. V. was pleased, although this was not directly related to Frank's employment goals.

> ONE COULD DESCRIBE BEHAVIORAL ACTIVATION AS A NIKE FORM OF THERAPY, GUIDED BY THE DICTUM "JUST DO IT." SIMPLISTIC THOUGH IT **SOUNDS, IT CAN BE REMARKABLY EFFECTIVE.**

The next week Frank mentioned that he had used leftovers from his bench project to make a "gym" for his parrots to play on. He showed Dr. V. a photograph: rather than a crude piece of work, it had a beautifully curved shape, with perches and swings. Dr. V. was blown away by what looked like a high-end piece of art and suggested that he spend more time doing what clearly gave him great satisfaction.

Over the following weeks the newly energetic Frank created one elegantly designed bird item after another, which he photographed and listed for sale on the Web. Orders rapidly arrived, and in the coming months Frank launched a new career. After Googling "bird accessories," Dr. V. was amazed by how Frank's creations outshone those of his competitors, who tended to build clunky kitsch. In contrast, his work was sophisticated and well crafted. It invariably received the highest praise from a growing base of customers. Frank's biggest problem was keeping up with orders. In therapy he and Dr. V. discussed whether he should raise prices because slim profit margins made it hard to cover his living costs. The therapy continued, now focused on the challenges of managing a growing business.

Frank's case—of a sudden burst of activity after prolonged inertia—is not unique: researchers have described many cases of what has been termed "sudden gains" with BA therapy as well as other forms of treatment for depression. A 2012 study led by Kallio Hunnicutt-Ferguson of Northwestern University suggests that about a third of patients treated with BA will experience such gains, in which a slow trajectory is followed by rapid improvement. Research led by Gabriel Dichter of the University of North Carolina at Chapel Hill, using functional magnetic resonance imaging, shows that BA therapy causes reactivation of the brain's reward circuitry, which involves the nucleus accumbens and the neurotransmitter dopamine. Depression is characterized by decreased activity in those areas of the brain and by increased ruminations and negative thoughts—overactivation of brain areas related to self-thoughts and internal focus, such as the default mode network. In fact, new research suggests that SSRI medications often do *not* improve the depressed brain's sluggish reward circuitry. BA therapy may be a *specific* way of reactivating reward circuitry as a part of recovery from depression.

This possibility led me—along with several colleagues—to conduct a pilot study of BA with 16 patients with major depression who, like Frank, had responded to medication but could not restart their work life. The study, published last year in *Comprehensive Psychiatry,* found that 69 percent (11 patients) were subsequently able to increase their work hours, find a new job or, like Frank, create their own business. Why this sudden activation occurs in some BA patients while others linger in a seemingly interminable limbo is a question I continue to explore.

When I see Frank these days, he seems in many ways to be a different person than he was a few years ago. Recently, for the first time in a decade, he began dating. Though still vulnerable to recurrences of low mood and pessimism, he is enthusiastic and energetic and shows initiative and creativity. He is clearly engaged in the world again in a meaningful way. M

MORE TO EXPLORE

- **Randomized Trial of Behavioral Activation, Cognitive Therapy, and Antidepressant Medication in the Acute Treatment of Adults with Major Depression.** Sona Dimidjian et al. in *Journal of Consulting and Clinical Psychology,* Vol. 74, No. 4, pages 658–670; August 2006.
- **Behavioral Activation Therapy for Return to Work in Medication-Responsive Chronic Depression with Persistent Psychosocial Dysfunction.** David J. Hellerstein et al. in *Comprehensive Psychiatry,* Vol. 57, pages 140–147; February 2015.

BANKING AGAINST ALZHEIMER'S

Research has provided a host of clues to age-proofing our brains and making them more resistant to dementia

By David A. Bennett

CG IMAGERY BY JUSTIN METZ

I have loved archaeology since middle school and have spent many vacations dragging my wife and kids around the world visiting ancient ruins—from the Anasazi kivas of the American Southwest to the "lost cities" of Machu Picchu and Petra to the big-headed Moai statues towering over Easter Island. Somewhere along the way, medical school and a neurology residency derailed my affair with the subject. But even now I sometimes imagine myself as a brain archaeologist—delicately picking through preserved specimens, cataloguing biological artifacts and trying to align my findings with people's unique histories.

I have been lucky to have plenty of opportunity to indulge this daydream. At the Rush Alzheimer's Disease Center in Chicago, where I am director, about 100 scientists are searching for ways to treat and prevent a range of common neurodegenerative disorders. For nearly a quarter of a century I have led two longitudinal investigations—the Religious Orders Study and the Rush Memory and Aging Project—which have enrolled more than 3,200 older adults across the U.S. Our volunteers enter these studies, dementia-free, anywhere from their mid-50s to their 100s and, remarkably, agree to hours of testing each year. They undergo comprehensive physical examinations, detailed interviews, cognitive testing, blood draws and, in some cases, brain scans. Most important, all of them donate their brain after death to our research. The resulting collection fills various cabinets and two "freezer farms"—maintained at –112 degrees Fahrenheit and protected by backup and alarm systems—covering about 4,000 square feet.

To date, we have conducted tens of thousands of clinical evaluations and more than 1,350 autopsies, generating an unprecedented set of data that we share with researchers around the world. Like archaeologists in the field, we sift through the remains in our care in hopes of understanding why some people stay sharp into their second century while others begin to lose their faculties as early as their 60s. We link risk factors and lifestyle choices to cognitive function and the biological footprints of disease. It is time-consuming work—the ultimate test of delayed gratification. You might think the more actual damage we find in the brain, the more cognitive challenges its owner experienced—and this is generally true. But not always. Sometimes, given two people with comparable amounts of brain injury, only one of them will have suffered ill effects [*see box on page 34*].

In fact, it is rare to grow old with a completely healthy brain. Virtually every brain we examine exhibits at least some of the neuron-killing tangles associated with Alzheimer's disease, by far the most common cause of dementia. In about half, we find the scars of a previous stroke, big or small. And in almost a fifth, we discover so-called Lewy bodies—abnormal protein clumps that are the mark of Parkinson's disease and Lewy body dementia. But when we trace these laboratory finds back to each individual's records, we can account for only about half of the cognitive changes we measured on tests of memory, processing speed, and the like. Put another way: the condition of someone's brain postmortem only partially tells us how well it functioned in the years leading up to the person's death.

The big question, of course, is, Why do some people develop symptoms of Alzheimer's dementia, and others do not? To a certain extent, genetics come into play; some people are unlucky to inherit high-risk genes associated with the disease. But investigators working with our data have also identified many key lifestyle factors that shape our brain's health into old age [*see box on page 36*]. Some—such as a healthy diet—probably help to slow the buildup of toxic materials that can cripple memory and critical thinking. For instance, Rush epidemiologist Martha Clare Morris has found that the so-called MIND diet—which is rich in berries, vegetables, whole grains and nuts—dramatically lowers the risk of developing Alzheimer's.

But other life choices seem to actually bolster the brain's ability to cope with the disease, helping it compensate for any loss of mental firing power. In particular, we have found that the more en-

FAST FACTS

STAYING SHARP

1. Several large longitudinal studies are offering important clues about how we can bolster our brain to better withstand the physical changes that come with aging.
2. Virtually all brains in old age contain some pathological signs of Alzheimer's disease, but only some people suffer any symptoms as a result. Those who do not develop dementia appear to have greater cognitive reserve to fall back on.
3. Choices we make throughout life, from learning a second language or studying music in childhood to finding purpose and remaining physically, intellectually and socially active in retirement, can build cognitive reserve and dramatically reduce the risk of developing dementia.

PRECEDING PAGE: VIKTOR GLADKOV @iStock.com (*stack of coins*)

gaged our volunteers stay throughout life—physically, socially and intellectually—the more resilient they are to dementia at its end.

We are beginning to understand exactly where this resilience comes from in some individuals, raising the hope that we might be able to prevent Alzheimer's in many more—or at least delay its onset so that death comes first. From the dawn of humankind until roughly half a century ago, death did typically come first; most of us did not live long enough to worry about neurodegenerative diseases. As life spans have lengthened, however, Alzheimer's has become increasingly prevalent and now affects more than five million Americans older than 65, or roughly one in nine. Diagnoses are forecast to triple by 2050. Our research suggests that we might be able to avert, or at least blunt, this looming crisis. Indeed, there are things we can all do—from childhood to our retirement years—to make our brain less vulnerable to the ravages of aging.

For around two decades Bennett (*above*) has led two large longitudinal investigations into Alzheimer's disease. All participants donate their brains after death. The collection, stored in specialized freezers (*right*), is yielding important clues about how to prevent the disease.

Laying Foundations

Alzheimer's was not always such an urgent matter. My grandmother was born in October 1906, when people had more reason to worry about communicable diseases than age-related ones. A month after her birth, neuropathologist Alois Alzheimer presented a novel case of dementia to a meeting of his colleagues, who were so unimpressed that they did not ask a single question. The patient, a middle-aged woman named Auguste Deter, had not had syphilis, then considered a major cause of dementia. So instead Alzheimer attributed her symptoms to distinctive hard plaques he observed during autopsy between the nerve cells in her brain and odd tangles of fibers within the cells.

Today we know that these classic features are accumulations of malfunctioning proteins—mostly misfolded fragments of beta-amyloid in the plaques and abnormal tau in the tangles. For several decades after Alzheimer's discovery, though, the disease and its mysterious pathology remained largely forgotten. Then, between 1968 and 1970, neuropathologist Sir Bernard Tomlinson and his colleagues at Newcastle University in England ran a series of elegant studies that led to an important insight: older people without dementia often had plaques and tangles in their brain, too. Those with dementia just had more—and also suffered more strokes. The findings suggested that Alzheimer's disease might be far more common than anyone had realized.

Evidence for this began to accumulate. In April 1976 the late neurologist Robert Katzman, then at the Albert Einstein College of Medicine, penned a landmark editorial in the American Medical Association's *Archives of Neurology* in which he declared Alzheimer's disease a "major killer." The floodgates were

PHOTOGRAPHS BY *Todd Winters*

opened, and a trickle of money began to flow into laboratories across the country. Between 1984 and 1991 the nascent National Institute on Aging funded 29 dedicated research centers, including our own. From the start, our primary interest was how to prevent Alzheimer's. Such efforts were in their infancy, but we hoped to take an original approach. Rather than limiting our investigation to the connection between potential risk factors and Alzheimer's dementia, as others were doing, we decided to also take into consideration the physical changes associated with aging and disease in the brain itself.

One big challenge was getting our hands on enough brains, especially from people *without* dementia. It is relatively easy to get organ donations from patients brought to an Alzheimer's clinic by concerned family members. Obtaining brains from healthy older people—who will also need to agree to multiple examinations before death—proves far more difficult. But we knew that nonsymptomatic people were a vital part of the puzzle. In a revealing 1988 study, Katzman performed autopsies on 137 former residents of a nursing facility, roughly half of whom had previously received an Alzheimer's diagnosis. Among the other half, though, he spotted 10 with significant Alzheimer's-related damage in the brain—who were also among the top-scoring residents on tests of cognitive performance. This group, Katzman noted, had higher brain weights and more neurons than the others with similar amounts of pathology. So by way of explanation, he proposed that maybe these people just had more brain to lose—an idea that sparked our interest in what is now referred to as neural or cognitive reserve.

How many more people like that were there? Could anyone bank this kind of mind-saving surplus? We planned our investigation to find out, taking inspiration from the Nun Study founded in 1986 by epidemiologist David Snowdon, now retired from the University of Kentucky. The Nun Study tracked nearly 700 members of the School Sisters of Notre Dame older than 75—a high percentage of whom donated their brain after death. Our plan was to complement, not copy, the Nun Study. With the help of the Chicago Archdiocese and the late Sister Katie McHugh, we networked with Catholic orders across the country. By 1993 we had secured funding to launch the Religious Orders Study, requiring organ donation for all participants at sign-up. Four years later we received additional funding to start the Rush Memory and Aging Project to study lay retirees.

As scientists, we cannot engage in paradigm-shifting work if our studies are inextricably tied to the existing framework. So we deliberately designed our experiment to be free from as many assumptions about aging and Alzheimer's as possible. For instance, there are no inclusion or exclusion criteria other than being old enough and

agreeing to organ donation. We ask our participants not only about their diet, sleep and exercise—widely known to affect health and aging—but also about their education, musical training, foreign-language skills, personality, social activities, traumatic experiences, socioeconomic status as children, and more. We analyze how all these variables relate to changes in the brain and symptoms of dementia, ignoring conventional diagnostic labels. We track how people's cognition changes, sometimes improving, but all too often declining. And we note the pace: some people run through the disease's course quickly, whereas others decline slowly or not at all. Our key question: How do you get into that latter group?

Your Brain Fights Back

My grandmother lived to be nearly 100 and liked to tell me repeatedly: "Aging isn't for sissies!" Given my professional focus on aging and dementia, she did not have to tell me twice. Clinically, Alzheimer's can be devastating. Over time it robs people of their memories, use of language, attention and independence. I often compare the deepening memory issues to losing pages from a chronological photo album of your life from back to front—with childhood memories the last to go. Ultimately sufferers lose the ability to function on any meaningful level. Mercifully, perhaps, many people die from other conditions long before reaching the end stages of the disease. The good news is that as the disease unfolds, the brain fights back. Like all other systems in the body, the brain does not sit idly by, a mere bystander. In fact, the brain is the most plastic and adaptable of all our organs (which is how you learn in the first place). This plasticity appears to be a large part of what constitutes our reservoir of resilience or cognitive reserve.

To better understand it, we scrutinize the brains of people who seemed to have real cognitive staying power—or declined only slowly—despite the presence of plaques, evidence of stroke or other damage. Like Katzman, we find that such individuals tend to have more neurons—specifically in the locus coeruleus, a blue-tinted region in the brain stem normally involved in our stress and panic responses. The finding makes sense: most Alzheimer's patients eventually lose up to 70 percent of the neurons there. Working with psychiatrist William Honer of the University of British Columbia, we also discovered that slow decliners typically have higher amounts of specific proteins, such as vesicle-associated membrane protein (VAMP), complexin-I and complexin-II, which help to relay messages across the synapses, or gaps, between brain cells.

> The brain is the most adaptable of all our organs. As Alzheimer's unfolds, it fights back, drawing on cognitive reserve.

Using our samples, neuroscientist Bruce A. Yankner of Harvard University discovered yet another protein that helps to actively preserve our mental abilities. Levels of this protein, called repressor element 1–silencing transcription factor, or REST, are highest in the brains of elderly people who live into their 90s and 100s. Perhaps not surprisingly, Yankner found in animal studies that REST protects neurons from death caused by oxidative stress or beta-amyloid, among other threats. His research shows that better cognition correlates with high levels of REST in the cortex and hippocampus, areas that are normally vulnerable in Alzheimer's. And when the researchers disabled REST in mice, the animals began to show signs of Alzheimer's-like neurodegeneration.

We and other researchers continue to search for additional biochemical factors that help save our mind as we age—plus other mechanisms that cause it harm. Recently neurologist Julie Schneider in our group at Rush uncovered the fact that more than half of the brains in our collection contain abnormal clumps of the protein TDP-43, previously linked to frontotemporal lobe dementia and amyotrophic lateral sclerosis (Lou Gehrig's disease). Nearly 10 percent also bear scar tissue and a major loss of neurons in the hippocampus, critical to memory formation.

Others have observed signs of chronic inflammation in the brains of Alzheimer's patients, possibly supporting theories that tie the disease to infections such as human cytomegalovirus, which psychologist Lisa Barnes in our group confirmed is associated with lost cognition. And in collaboration with neurologist Steven Arnold, now at Massachusetts General Hospital, we found evidence of an association between Alzheimer's and abnormal insulin signaling in the brain.

This biological complexity has important implications for how we think about the treatment and prevention of this disease. With so many variables involved and likely many more to be discovered, it is not surprising that a lot of risk factors for Alzheimer's dementia are not actually related to Alzheimer's pathology. Working with neurologist Philip De Jager of Brigham and Women's Hospital, we recently examined the relation of more than 25 genomic variants linked to Alzheimer's dementia to several different types of abnormalities in the brain. We found that a few correlated with Alzheimer's pathology, but some were associated with other

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Education can help secure brain health as we age. Bilingualism seems to delay the onset of dementia by as much as four years.

causes of dementia such as stroke, Lewy bodies and scarring in the hippocampus.

This complexity also means that it is exceedingly challenging—if not impossible—to single out meaningful targets for drug therapies. And given the imperfect correlation between brain pathology and cognitive performance, any interventions aimed at these biological processes would not necessarily have a large effect on symptoms. In fact, drug development for treating Alzheimer's has been slow and marked mostly by disappointment.

Building Cognitive Reserve

As researchers continue to untangle the intricate web of disease mechanisms, it makes sense to focus on preventing Alzheimer's in the first place—to apply what we know about strengthening our brain to withstand the hits that come with aging. In our work, we have homed in on a variety of experiences, from childhood through old age, that can help us shore up cognitive reserve. Perhaps one of the most critical early steps toward ensuring better brain health is education—and not just formal schooling but other kinds of learning as well. Cognitive psychologist Fergus Craik and his colleagues have estimated that, on average, bilingualism delays the onset of dementia by as much as four years. And neuropsychologist Robert Wilson in our group at Rush has found that training in a second language, as well as in music—another form of language—correlates with a slower rate of cognitive decline. Had I only continued with those violin lessons!

That said, the relation between education and cognitive decline is complicated, as statistician Lei Yu in our group at Rush has discovered. In general, cognitive decline does not occur at a steady pace; it begins at one rate, and then, after a certain point, it accelerates. More education shifts this so-called change point later in life, maybe because more learning builds more brainpower to fall back on. Those with fewer years of formal education tend to have lower baseline abilities to start with and hit the change point sooner. Before the change point, both groups lose cognitive skills at roughly the same rate. Interestingly, even though those with more education typically start their descent at a later age, once they reach the change point they decline much faster. Biostatistician Charles Hall of the Albert Einstein College of Medicine has also identified this pattern in analyzing data from the Einstein Aging Study, an investigation of aging in the brain that has tracked a group of Bronx, N.Y., residents for more than three decades.

How Did Marge Stay Sharp?

Sisters Betty Borman (*left*) and Marjorie Mason Heffernan (*right*) both participated in Bennett's study. Although his group found moderate signs of Alzheimer's in Marge's brain after death, she never showed any symptoms of dementia, consistently scoring high on tests of cognitive function.

COURTESY OF BETTY BORMAN

I first met Marjorie Mason Heffernan in January 2003, when I began recruiting participants for the Memory and Aging Project at a retirement community, now called Presence Bethlehem Woods, in La Grange Park, Ill., a 40-minute drive west of Rush University. I am not sure what took us so long to enroll there; it is right next door to the Sisters of St. Joseph, our very first Religious Orders site, where we had been testing study participants for a decade.

Roughly a month after she signed up for our study, Marge—as she was known to friends and family—came in for her baseline evaluation. During the first week of March, I sat down to review the results with her. At 79 years old, she was doing great. On the Mini-Mental State Examination (MMSE), the most widely used test of overall cognitive abilities, she had scored a perfect 30. In fact, she performed extremely well on nearly all the 21 cognitive tests we gave her.

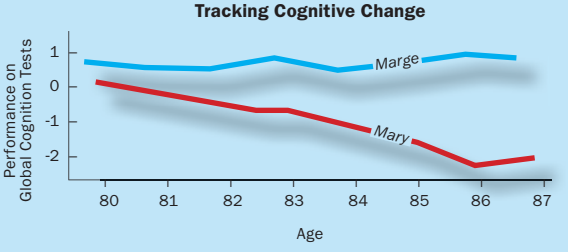
Over the course of seven years Marge proved to be an energetic study participant. She enrolled in a number of substudies—including a brain-imaging study and a behavioral economics and decision-making study. We evaluated her cognition eight times, and each time she scored a perfect 30 on the MMSE—apart from one test at age 80, in which she nearly scored 30, and one at age 84, when she dipped to 28. At the end of 2010, Marge died peacefully at home, at age 87, comforted by her son and two nieces.

Like all our study participants, Marge had generously donated her brain for research. At autopsy, it weighed 1,246 grams, pretty much average for women. She had mild, widespread tissue loss, which is typical of Alzheimer's and other neurodegenerative diseases but can also be seen in healthy older brains. Under the microscope, her brain had enough beta-

This precipitous downturn among the highly educated supports a theory called compression of morbidity, which James Fries, a professor of medicine at Stanford University, first put forth in 1980. Fries's basic hypothesis is that it is possible and desirable to delay the onset of diseases and compress the number of years someone spends ill and disabled at the end of life. For a disease such as Alzheimer's, being able to compress morbidity is hugely valuable, both emotionally and economically. This disease takes a terrible toll on both patients and family members, who are often put in the role of caregiver. Finding support is costly. Thus, any measure that can give someone even one more year of independent living translates into benefits not only for that person but for their family and the economy.

Among our participants, the more educated they are, the shorter, on average, their overall suffering. This trend explains a 1995 report by Yaakov Stern of Columbia University, which found that the risk of death among patients who have Alzheimer's dementia was greater for those with more education.

Education is not directly related to any neuropathology or protective neurobiology measured to date. Instead it seems to mute the effects of advancing disease on people's cognitive skills. The more damage someone has in the brain, the more protection he or she is afforded by extra years of education. This holds true at very high levels of education, as seen in our data, as well as at very low levels of education, as demonstrated by neuropathologist Jose Farfel of the University of São Paulo in Brazil.



While participating in the study, both Marge and another subject, Mary,* took annual tests of their cognition. Although the two women had similar levels of pathology, Marge's scores remained high and Mary's steadily declined.

amyloid plaques and tau tangles to meet the pathological criteria for Alzheimer's. There were no signs of infarcts (areas of dead tissue that can indicate stroke) or Lewy bodies (marks of Parkinson's disease and Lewy body dementia). In short, the findings were consistent with moderate Alzheimer's, which raised the question: Why was Marge's cognition so good?

The answer might be found in her life story, which featured many of the factors that our studies indicate can boost cognitive reserve and hold dementia at bay. For one thing, she was well educated—having attended school for 22 years, a lot for a woman born in 1923. Her younger sister, Betty Borman, who joined our study after Marge's death, later relayed that both she and Marge graduated from Chicago Teachers College in the 1940s.

From the data we collected, I knew that Marge was cognitively and socially active. Betty later described her sister as a voracious reader, who could get through a book in a day. She told me that Marge founded a book club and that she and her late husband were involved in a local theater company. Marge also maintained a positive attitude, despite many adversities: she buried two of her three sons and two husbands.

Tests of Marge's personality and well-being backed up Betty's description. She had scored high on "purpose in life" and conscientiousness and low on neuroticism, anxiety, depressive symptoms and harm avoidance, a trait that encompasses shyness, excessive worrying and pessimism. Despite having a bad back, Marge was no homebody and scored the maximum possible in "life space"—a measure of one's geographical range—on our survey.

It is interesting to contrast Marge with another of our female participants, Mary.* She also enrolled at age 79 and, like Marge, completed eight annual clinical evaluations before her death at age 87. Mary's MMSE score at baseline was a solid 28 but declined to half that at her final evaluation. She was diagnosed with mild cognitive impairment at age 81, dementia at 84 and Alzheimer's at 85.

At autopsy, Mary's brain weighed 1,088 grams, much smaller than Marge's. And unlike Marge's brain, hers showed scarring from three small infarcts, although she had no history of strokes. But like Marge, Mary had mild tissue loss and enough damage to meet the pathological criteria for Alzheimer's. She actually had less beta-amyloid and fewer tangles than Marge did.

Despite having less Alzheimer's pathology than Marge, Mary suffered from a progressive loss of cognition, resulting in an inability to care for herself by the time of her death. Yes, she had a couple of small infarcts and some beta-amyloid in her blood vessels, and there may have been genetic differences that made Mary more vulnerable. But again, we found clues to her cognitive decline in her life story: Mary had 10 fewer years of education than Marge, having graduated only from high school. She scored low on measures of cognitive activity, purpose in life and life space. And she scored very high on harm avoidance, anxiety, neuroticism and depressive symptoms.

All efforts to develop therapies to prevent Alzheimer's have so far failed, but the comparison of these two women brings into focus the potential protective effects of life habits—ranging from early education to late-life social engagement. Marge and Mary had similar levels of Alzheimer's-related damage, yet their brains functioned at very different levels during their final years of life. *—D.A.B.*

COURTESY OF DAVID A. BENNETT

**Not her real name.*

ROB MELNYCHUK *Getty Images*

BUILDING A BETTER BRAIN AS WE AGE

Based on the results of scores of studies, here are 10 things you can do to reduce the risk of losing cognition and developing Alzheimer's dementia:

1. Pick your parents well! Make sure you get good genes, a good education, a second language and music lessons. Avoid emotional neglect.
2. Engage in regular cognitive and physical activity.
3. Strengthen and maintain social ties.
4. Get out and explore new things.
5. Chillax and be happy.
6. Avoid people who are downers, especially close family members!
7. Be conscientious and diligent.
8. Spend time engaged in activities that are meaningful and goal-directed.
9. Be heart-healthy: what's good for the heart is good for the brain.
10. Eat a MIND diet, with fresh fruit and vegetables and fish.
11. (For *This Is Spinal Tap* fans, our list goes to 11.) Be lucky!

Mining the Golden Years

If you don't play the violin or speak another language, don't fret. Early educational experiences are not your only shot at building cognitive reserve. We have also found various factors later in life that can buy more years of healthy living. Among them is something commonly called purpose in life, a measure of well-being that refers to our psychological tendency to derive meaning from life's experiences and to have clear intentions and goals.

Neuropsychologist Patricia Boyle in our group at Rush measured this trait in more than 900 participants in the Rush Memory and Aging Project, the majority in their 70s, 80s and 90s, using a scale based on the work of psychologist Carol D. Ryff of the University of Wisconsin–Madison. During up to seven years of follow-up, we discovered that those who scored higher on purpose in life were 2.4 times more likely to have avoided an Alzheimer's diagnosis, compared with those with lower scores. Relatively higher scores were also associated with slower rates of cognitive decline. In a similar analysis, Wilson found that higher levels of conscientiousness—one of the classic "big five" personality traits, characterized by organization, self-discipline, dependability and a drive to achieve—also offered some protection: participants in the Religious Orders Study scoring in the 90th percentile in conscientiousness had an 89 percent reduction in risk for developing Alzheimer's.

Psychological traits aside, other studies show that the size of our communities can affect how quickly Alzheimer's pathology encroaches on our cognition: among our participants, those with larger social networks are better able to postpone some of the worst symptoms. By social networks, we do not mean Facebook friends or Twitter followers but rather close relatives and friends with whom you can discuss private matters. Our first thought was that perhaps people with large social networks engage in more cognitive, physical and social activities, but controlling for these variables does not affect the association. Instead the protection from larger social networks might reflect in part the type of individuals who can form them. Simply put, they may have better developed people skills—and so a greater reserve of social cognition—to fall back on.

Physician Laura Fratiglioni, a professor at Sweden's Karolinska Institute, was first to describe the link between social networks and Alzheimer's in 2000. She based her findings on data from the Kungsholmen Project, a longitudinal population–based study on aging and dementia in Stockholm. Interestingly, she also measured how satisfied people were with their social contacts and found that frequent but unsatisfactory interactions with your children increases dementia risk. (It reminds me of an old Sam Levenson joke: "Insanity is hereditary—you get it from your children!")

All humor aside, Wilson in our group examined negative social interactions in a 2015 study, following 529 of our participants. All were symptom-free at the start of the study, but in keeping with Fratiglioni's finding, after an average of nearly five years, those who reported more neglect and rejection were more likely to show signs of cognitive impairment.

The central theme behind all these influences is positive engagement. We and many others have found that increases in cognitive, physical and social activities are all associated with a reduced risk of Alzheimer's dementia. Neurologist Aron Buchman in our Rush group went so far as to periodically place actigraph units (similar to pedometers) on the wrists of nearly 1,000 participants to measure their physical movements—capturing not just formal exercise but any activity, like playing cards or cooking. His results showed that those in the bottom 10 percent of intensity—the people who moved the least—were more than twice as likely to later be diagnosed with Alzheimer's, compared with the most mobile in the study. The implied lesson for us all: keep moving.

Staying active, seeing friends, being conscientious and feeling a sense of purpose in life all appear to reduce the risk of Alzheimer's disease.

Another way to think about engaging with the world is to actually get out there. Epidemiologist Bryan James in our Rush group tested something referred to as life space among nearly 1,300 of our volunteers, none of whom showed signs of dementia at the start of the study. In essence, they measured the subjects' range during the previous week: Had they left their bedroom, front porch or yard? Had they ventured out of their neighborhood? Or had they made it farther afield and out of town? After about four years they found that those most constricted to their homes were twice as likely to develop Alzheimer's compared with those with the largest life spaces—controlling for cognitive, physical and social activity. Is it the motivation to get up and go, or is it what you do when you get there?

We hope that in the years to come, as our collection expands and our means to study it grow ever more sophisticated, we will find many more clues to age-proofing our brain. When I used to visit my grandmother—we called her GG for "great grandmother"—at her retirement facility, she would always ask me, "So, David, still working on the Alzheimer's?"

"Yes, GG," I would answer. "Still examining old brains trying to figure out what protects us from memory loss."

She always followed with, "Find anything?"

"Sure," I'd say, "a little."

Then she'd lean over, point to a few people in her facility and whisper, "You better hurry up!"

How right she was. **M**

MORE TO EXPLORE

- **Overview and Findings from the Religious Orders Study.** David A. Bennett et al. in *Current Alzheimer Research,* Vol. 9, No. 6, pages 628–645; July 1, 2012.
- **Overview and Findings from the Rush Memory and Aging Project.** David A. Bennett et al. in *Current Alzheimer Research,* Vol. 9, No. 6, pages 646–663; July 1, 2012.
- **Building a Pipeline to Discover and Validate Novel Therapeutic Targets and Lead Compounds for Alzheimer's Disease.** David A. Bennett, Lei Yu and Philip L. De Jager in *Biochemical Pharmacology,* Vol. 88, No. 4, pages 617–630; April 15, 2014.
- **Conscientiousness, Dementia Related Pathology, and Trajectories of Cognitive Aging.** Robert S. Wilson et al. in *Psychology and Aging,* Vol. 30, No. 1, pages 74–82; March 2015.
- **Residual Decline in Cognition after Adjustment for Common Neuropathologic Conditions.** Lei Yu et al. in *Neuropsychology,* Vol. 29, No. 3, pages 335–343; May 2015.

From Our Archives

- **Seeds of Dementia.** Lary C. Walker and Mathias Jucker; *Scientific American,* March 2015.
- **Lifting the Curse of Alzheimer's.** Gary Stix; *Scientific American,* May 2015.
- **Brain Drain.** Maiken Nedergaard and Steven A. Goldman; *Scientific American,* March 2016.

Exceptional talent and mental toughness have helped superelite sprinter Usain Bolt win six Olympic gold medals—so far.

THE RIGHT STUFF

What psychological and physical traits separate the world's best athletes from the rest of us?

By Rachel Nuwer

Is it his drive, his "wingspan" or the combination that has propelled Michael Phelps to win 22 Olympic medals?

Every Summer Olympics features a handful of superhumans the likes of Usain Bolt, Gabby Douglas and Michael Phelps. Rio will be no exception. With shows of supreme physical strength and grace, the standouts in the 2016 Games will sprint, flip and glide their way through a gauntlet of grueling events. They will captivate the crowds, smash records and, in all likelihood, leave Brazil with an impressive haul of gold.

But what, exactly, sets these superelite athletes apart? It has long been a matter of heated debate. Historically, experts and sports fans alike have believed that genes are primarily responsible for such extraordinary achievement: top athletes are simply born with superior physical traits that allow them to outperform everyone else. During the past three Summer Games, for instance, many analysts credited Phelps's stunning success in the pool—winning him a total of 22 medals—to his 80-inch "wingspan" and hyperflexible, flipperlike size-14 feet.

Since the 1990s, though, another school of thought has gained considerable traction—namely, the idea that inborn talent is not, in and of itself, enough to reach the highest echelons in sport. No matter how good someone is by nature, genuine expertise also demands certain psychological traits, as well as years of hard work and first-rate coaching [see "How to Coach Like an Olympian," on page 45]. Sports psychologists are finding, for instance, that the experience of overcoming major emotional challenges can sometimes instill extra resilience in young athletes and fuel their exceptional drive. Genes, meanwhile, make a difference in how much individuals respond to training in addition to shaping their baseline gifts.

"For a long time people believed either you had innate talent or you didn't," says K. Anders Ericsson, a psychologist at Florida State University who coined the term "deliberate practice" for a training approach that involves goal setting, repetitions of component skills, mental rehearsals and immediate feedback—now seen as critical for elite athletes. His work, described in a new book, *Peak: Secrets from the New Science of Expertise,* debunks the idea of "naturals" who seem to come out of nowhere but have often just switched sports. "I've always found plausible alternative accounts that involve prior purposeful practice," Ericsson says.

In truth, going for gold probably always takes huge amounts of genetically bestowed potential, mental toughness *and* first-class training—as well as lots of luck to avoid injury, to connect with the right coach, and to find the best resources and support.

FAST FACTS
GOING FOR GOLD

1. Research suggests that it takes just the right mix of physical talents, personality traits and life experiences to reach the top echelon in any competitive sport.
2. Elite athletes tend to have higher levels of inborn ability, a greater capacity for gaining fitness, and more experiences of mental states called "flow" and "making it happen." They also excel at certain perceptual and cognitive tasks, compared with nonathletes.
3. Furthermore, one study has found that so-called superelite athletes, who consistently win major medals, have often experienced a traumatic event early in life.

PRECEDING PAGES: PHIL NOBLE *Reuters Pictures;* THIS PAGE: JEFF HAYNES *Reuters Pictures*

Fast, Faster, Fastest

Jerry Baltes, head cross-country and track coach at Grand Valley State University, often tells new recruits, "I can make you faster, but I can't make you fast." In fact, even among the already fast, so-called trainability varies. Levels of intrinsic fitness and achieved fitness—or what you can attain through training—are evaluated based on traits such as muscle strength and cardiorespiratory fitness, itself normally measured by the volume of oxygen the body consumes in a minute. Both can differ dramatically from one person to the next. For instance, a young Olympian may have three times the maximum oxygen uptake as an elderly person in poor health—and twice that of an unfit person the athlete's same age.

For some, achieved levels of fitness are hard to shift, no matter how much drive they have—in which case, pushing too hard can lead to overtraining instead of improvement [*see box on next page*]. When exercise scientist Nir Eynon of the Institute of Sport, Exercise and Active Living (ISEAL) at Victoria University in Australia and his colleagues subjected sedentary people to the same carefully controlled exercise programs, they found that some made almost no gains; at the same time, others increased their cardiorespiratory fitness by as much as 50 to 80 percent. "If you take two people—you and me—and we start at the same baseline and do exactly the same training and eat the same diet, we would both gain aerobic capacity, or muscle mass—or whatever—very differently," Eynon says.

Elite athletes most likely are among a subset of people who reap the greatest benefits from training on top of high baseline levels of fitness. In 1998 geneticist Claude Bouchard of Pennington Biomedical Research Center of the Louisiana State University System and his colleagues found that both intrinsic and achieved levels of fitness tend to aggregate in families. When they tested 99 families, heritability explained about 50 percent of the variance in maximum oxygen uptake, for example. But Bouchard found no correlation between inborn fitness and trainability.

Of course, it all starts with the inborn gifts—as one 2014 study underscored. Evolutionary biologist Michael Lombardo of Grand Valley State University and his colleagues surveyed 15 male and female Olympic sprinting champions and the 20 fastest American men in U.S. history and found that, among those for whom biographical data were available, all were exceptionally fast before undergoing any formal training. Likewise, 64 collegiate championship-level sprinters and throwers in the same study all recalled being faster or stronger and better at throwing, respectively, than their peers as children. Of significance, the elite sprinters also showed big jumps in ability once they began formal training. "Strength, agility, speed and other athletic traits are all phenotypes that arise from interactions of the genotype with the environment," Lombardo says. "To deny that there is any genetic variation in individuals that results in differences in athletic ability is really denying what we know about biology."

That said, those underlying genetics have proved elusive. In 2016 Bouchard and his colleagues compared common alleles—or variants of a given gene—in 1,520 elite endurance athletes with 2,760 matched control subjects from four continents and came up completely empty-handed. "We thought we were in good shape to identify alleles, but it turns out that wasn't true at all," he says; the team "failed miserably," uncovering "not even one single allele reaching statistical significance." The takeaway? Athletic ability probably arises from multiple gene variants, all with very small effect sizes. One such variant, though, may be *ACTN3*—a gene responsible for producing a protein used by fast-twitch muscle fibers, which contract quickly and provide bursts of power.

Athleticism and trainability are partially inherited, giving sisters such as Serena (*left*) and Venus (*right*) Williams an edge.

In work that spanned more than a decade, geneticist Kathryn North of the University of Melbourne in Australia and her colleagues found that mice with *ACTN3* have greater endurance. Eynon and his team at ISEAL are currently looking to prove the same link in humans. As he puts it, "We think you need this pro-

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GETTY IMAGES

tein to sprint very fast." About 16 percent of humans are naturally deficient. In contrast, among 300 world-class sprinters, Eynon and his colleagues found that deficiency approaches 0 percent, although it accounts for just 1 to 1.5 percent of the variance in total sprinting ability. "All that we can say with a very high level of certainty about this gene is that if you are deficient in it, you probably will not be an elite sprinter," Eynon says.

Making It Happen

In addition to fitness levels, scientists have found telling mental traits that differentiate top athletes from amateurs. First, those competing at the national or international level appear to have more experiences of what is described as flow—a state of deep absorption in an activity during which performance seems to happen effortlessly and automatically. They are also more likely to feel something trainers call "making it happen"—involving intense focus and effort under pressure. Researchers suspect that athletes are not only better at channeling these mental states naturally but that they also sharpen them by having ample opportunity to experience them.

"There are certainly times athletes can win without experiencing flow or making it happen," says sports psychology researcher Christian Swann of the University of Wollongong in Australia. "But when they do something excellent that they perceive as being close to their best performance, typically it will involve one of those states and sometimes both." Swann and his colleagues are writing up new findings indicating that specific personality traits—including confidence, competitiveness, adaptive perfectionism (a form that relishes achievement while tolerating mistakes and avoiding self-criticism), optimism and mental toughness—seem to predispose individuals to achieving flow states.

Athletes also excel at certain perceptual and cognitive tasks. In 2013 Heloisa Alves, a cognitive neuroscientist then at the University of Illinois at Urbana-Champaign, and her colleagues recruited 87 elite Brazilian volleyball players and 67 matched controls to perform a number of tests of executive control, memory and visuospatial attention. Compared with nonathletes, the volleyball players demonstrated faster reaction times in two executive-control tasks and one visuospatial-attentional processing task, as well as greater mental control.

"Our basic understanding is that longtime physical training, specifically in sports, also involves some cognitive training, including attention and executive control," Alves says. "So when you become an elite athlete, you somehow become an expert in certain cognitive abilities as well."

The highest echelon of sportsmen and sportswomen may also have additional

The Overtraining Trap

For Olympians and other serious competitors, pushing too hard can mean falling into a physiological and mental abyss **By Sarah Tuff Dunn**

ANDY LYONS *Getty Images*

Two years after breaking my leg in a freak running accident, I was logging up to 100 miles a week on the treadmill in preparation for a 36-hour adventure race. A veteran of 15 marathons and countless other athletic events, I was in peak physical shape. Or so I thought—until one Sunday morning when I could barely lift my arms. After years of lifting weights, I was too tired to lift the laundry basket. My own fitness, it seemed, had felled me. Was it overtraining? Had I pushed so far beyond my limits that my body could no longer keep up?

"Anyone who does endurance sports plays with the concept of overreaching," says Jeffrey B. Kreher, a sports medicine specialist at Massachusetts General Hospital. "But overtraining is when the ability to tolerate stress is greatly diminished for whatever reason. The homeostasis of the body has reached its tipping point." Kreher and fellow physician Jennifer Schwartz, now at Beth Israel Deaconess Medical Center, published a comprehensive review of the condition—"Overtraining Syndrome: A Practical Guide"—in 2012 in *Sports Health.*

In practice, overtraining can be hard to diagnose. Among the first signs are performance plateaus or declines. Resting heart rates can shift either up or down. Extreme fatigue and sore muscles set in. Ultimately overtraining disrupts the delicate balance of multiple systems, throwing off hormones, the immune system, behavior and mood. These effects can cause a confusingly broad range of possible symptoms—insomnia, irritability, anxiety, weight loss, anorexia, a loss of motivation, a lack of concentration and depression.

THE AUTHOR

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psychological differences, according to scientists who conducted studies for UK Sport, a governmental organization that promotes elite sports and athletic development. Specifically, UK Sport asked researchers to elucidate the fine-grained differences between elite athletes—professionals who compete at the Olympics or other major championships but who usually do not take home a major medal—and the so-called superelites who consistently win. UK Sport hoped to use its findings to foster more superelites and increase Britain's Olympic prowess.

Sports psychologist Tim Woodman and his colleagues at Bangor University in Wales, collaborating with other universities and UK Sport, took up the effort, recruiting 32 male and female British athletes: 16 superelites who had won two to 18 medals each, including at least one gold, at major world championships, and 16 matched elites, who had never won a medal but had competed at the same level. The researchers interviewed the participants, their coaches and their parents, asking questions about the athletes' life histories. Because these interviews generated more than 8,400 pages of data, the researchers turned to a novel pattern-recognition program to identify differences among the groups.

What they found took them by surprise. "There's a long-standing view that happiness makes people achieve, but this study blows that assumption out of the water," Woodman says. "Not only is happiness not the key, but it doesn't feature anywhere along the way." Indeed, the team found that all of the superelites had experienced a critical negative event—their parents' divorce, a death, disease or some other perceived loss—early in life. And shortly after, all managed to discover sports, which they uniformly recalled as a highly positive turn, changing their course almost immediately. "Suddenly they felt valued, important and inspired, perhaps for the first time," says Matthew Barlow, a postdoctoral researcher in sports psychology at Bangor who collaborated with Woodman.

SUPERELITE ATHLETES EXPRESS AN OBSESSIVE NEED TO WIN AND ARE MORE LIKELY TO HAVE EXPERIENCED A MAJOR SETBACK IN CHILDHOOD.

Men and Women of Steel

Early trauma and recovery through sports were not all that Woodman and his colleagues found when they examined the life stories of superelite athletes.

No one knows what biological mechanism triggers the syndrome. One theory holds that it is caused by a breakdown of the hypothalamus, a brain structure that regulates many hormones, metabolic functions and the autonomic nervous system. "It's confounding," Kreher says. "It's a retrospective diagnosis, and fatigue doesn't mean you have overtraining syndrome. Not all depression is overtraining. An individual's stress tolerance has many different influences."

As Kreher and Schwartz point out in their review, trouble tends to begin when additional stressors appear in an athlete's life. "It might be excessive travel, it might be the pressure of the competition season, it might be monotony," Kreher explains, illuminating one reason why my own endless treadmill miles had left me at a dead end. He notes that Olympic athletes, who are under tremendous pressure, can be especially vulnerable to overtraining. Some experts estimate that about 60 percent of elite runners and about 30 percent of elite swimmers overtrain at some point during their career.

It is something long-distance runner and former Olympian Ryan Hall (*opposite page*) knows all too well. Once a favorite for this summer's Olympic Games, he withdrew in January because of extreme fatigue, following in the exhausted footsteps of famed triathletes Paula Newby-Fraser and Scott Tinley. When Hall called it quits, it was the end of a two-year battle with underperformance. Was it overtraining? Like me, he is not sure but comments: "If you want to run 2:04 for a marathon, you're going to have to train very, very long and intensely, and at some point that demand on your body will take its toll." For Hall, the toll was mostly physical. "If I tried to run," he says, "I felt like I weighed a million pounds and could hardly lift my legs." For others, though, the distress is mainly mental.

The best treatment for overtraining is rest—which may sound easy: just snooze on the couch until your strength returns. But that prescription presents a challenge to athletes who have been conditioned for decades to train and compete. For elite athletes such as Hall, Kreher adds, it also raises an existential question of "Now what?" After cutting his running to three days a week, 30 minutes a session, and adding weight training to his routine, Hall is once again enjoying his sport, although he has retired from elite events. "My energy feels better than it felt my entire running career," he reports. "It's a bummer not to be going to Rio, but I'm choosing to be grateful for the two Olympics I did get to go to."

There are no evidence-based ways to prevent overtraining, Kreher says, but adding miles gradually and learning to be more resilient to stress—along with getting enough calories, hydration, sleep and carbohydrates—are key fitness fundamentals. Focusing on feelings can also help keep energy levels up. By recording their postworkout moods, for example, collegiate swimmers in a multicounty study reduced burnout by 10 percent, Kreher says. "If you do physical activity and feel joy, rejuvenation and health afterward, then that's appropriate," he concludes. "If you feel it was work, then that's a sign to do something different."

I've been following that sage advice myself lately, and after a long period of exhaustion, I am back running again.

Top competitors often enter a mental state called "making it happen," involving intense focus under pressure.

Very often these individuals had experienced another critical turning point later on in their sporting career. Whether this event was positive, like switching to an inspirational new coach, or negative, like the death of a loved one, it caused the athletes to redouble their efforts. "This big midcareer event reminds them of that original loss and motivates them at a deep-seated level," Barlow theorizes.

This common narrative—from a loss to sports to deeper motivation—seems to shape the personality and outlook of superelites in predictable ways. For starters, Woodman says, "the importance of not losing is very keen." Superelite athletes often express an obsessive need to win, as opposed to a desire for fame, happiness or money, which motivates many of their less successful competitors.

They are also "far more ruthless and selfish in their approach to their sport," Woodman explains, not hesitating, for example, to split up with a spouse or partner if they think the relationship compromises their goals. And while less successful elite athletes tend to focus on beating opponents, the superelites put equal value on beating themselves and others. As Woodman says, "They always thought they could do better, no matter how well they performed."

Woodman and his team have presented their findings at UK Sport's annual World Class Performance Conference and plan to publish all their results later this year. Overall, he says, their study implies that those who do not experience a traumatic event early in life "are less likely to have the drive necessary for that obsessive level of achievement." No one is suggesting that coaches traumatize their protégés in hopes of unleashing a superelite, but there are some actionable lessons, Woodman notes. For example, talent scouts looking to develop Olympic athletes could keep an eye out for promising candidates "who had a rough ride somewhere along the way."

Eynon stresses that no matter how far work progresses on the genetics and other determinants of elite performance, the findings should never be used to exclude people, with coaches selecting only those with the most biological promise. If that seems far-fetched, there are already a few companies selling direct-to-consumer genetic tests. These products purport to identify sprinting and aerobic ability from DNA in saliva samples, but, Eynon says, all are based on weak science. He also notes that not all serious athletes are elite, especially in team sports, so even if a test for elite potential did exist, it should not be used as a deterrent for playing sports.

"There are players who really shine," Eynon says, "and ones who help. Don't you ever stop doing sports on the basis of a genetic test." If nothing else, taking part in a sport that you love gives you a deeper appreciation of those athletes who are able to compete among the world's best. M

MORE TO EXPLORE

- **Perceptual-Cognitive Expertise in Elite Volleyball Players.** Heloisa Alves et al. in *Frontiers in Psychology,* Vol. 4, Article No. 36. Published online March 7, 2013.
- **Genes for Elite Power and Sprint Performance: *ACTN3* Leads the Way.** Nir Eynon et al. in *Sports Medicine,* Vol. 43, No. 9, pages 803–817; September 2013.

From Our Archives

- **Training the Olympic Athlete.** Jay T. Kearney; *Scientific American,* June 1996.
- **The Will to Win.** Steve J. Ayan; April/May 2005.

DEAN ALBERGA *World Archery Federation via Getty Images*

Mike Krzyzewski, head coach of the gold medal–winning U.S. men's basketball team, emphasizes relationship building as a key strategy for success.

HOW TO COACH LIKE AN OLYMPIAN

Winners embrace a psychologically nuanced approach to motivating athletes

By Bret Stetka

When the U.S. men's basketball team takes the court on August 6, at the Olympic Games in Rio de Janeiro, its most powerful asset will be a five-foot 10-inch grizzled veteran with an unmatched record of wins. That would be coach Mike Krzyzewski, who led Team USA to Olympic gold in 2008 and 2012. Of the 76 games played under the watchful eye of "Coach K," the national squad won 75. As head coach of Duke University's Blue Devils for 36 years, he has a greater number of wins—more than 1,040—than any other Division I basketball coach in the history of the National Collegiate Athletic Association. He is second all-time in national championships, with five victories.

What, apart from staying power, does it take to stack up that kind of record? Sports psychologists have been examining that question for decades. Much research has focused on what it means to be a great "leader," but despite a multibillion-dollar industry of books and seminars on the subject, the concept of "leadership" remains nebulous, according to many sports psychologists. "We now know there is no one set of attributes that all great leaders possess," explains Daniel R. Gould, a professor of applied sport psychology at Michigan State University. Instead what seems to matter most is the kind of relationship a coach develops with his or her athletes and the ability to encourage autonomy and nurture motivation.

Coach K would not disagree. He has attributed his success, at least in part, to an epiphany he had while observing his family at the dinner table. Years ago he noticed how his wife, Mickie, and their three daughters engaged with one another; how each showed interest in the others' day; how in tune they were with one another's feelings and the feelings of others. Krzyzewski gradually developed a coaching philosophy and style built on solidifying his relationships with players and listening to them.

Despite the time-honored tradition of coaching à la drill sergeant, the disciplinarian style is gradually shifting toward this more psychologically nuanced approach, which is supported by volumes of research. That is not to say a good old-fashioned, foul-mouthed, locker-room ream-out is off-limits, but at the same time coaches at the pro and Olympic level know it is most effective to tap into the psychological dynamics of human social interaction—whether coaching a team or an individual athlete.

The Roots of Good Coaching

Good coaches are, above all, experts in motivation—an area that has been studied by psychologists for decades. Foundational work dates back to 1985, when Edward L. Deci and Richard M. Ryan, both at the University of Rochester, published a classic paper laying out what they called self-determination theory, a psychological model suggesting that much of our behavior is guided by internal motivations as opposed to external cues. Based on their own work and that of others, the authors identified three requirements—competence, relatedness and autonomy—that drive self-determination and that are essential to maintaining psychological health. Their ideas are now accepted as dogma and have largely been adopted by sports psychologists, many of whom believe that targeting these three areas is the key to effective coaching.

Competence is the most obvious goal of athletic training—becoming a winning athlete clearly requires a dedication to physically mastering your sport. Recent research shows that when coaches and teachers help athletes and students to become more competent, other aspects of the trainee's mindset improve, too. Encouraging competence drives motivation and improves mental state, concluded a 2007 study by psychologist Roch Chouinard and his colleagues at the University of Montreal. They reported that students intent on mastering a particular area of mathematics—a mindset that can be encouraged by teachers—put signifi-

FAST FACTS

A WINNING STRATEGY

1. Disciplinarian coaching is falling out of favor as more and more coaches realize the value of a more psychologically nuanced approach.
2. Many Olympics-level coaches emphasize the importance of relationships among players on a team and between coach and athletes.
3. Successful coaches also encourage autonomy, an essential pillar of self-motivation.

PRECEDING PAGE: ROB CARR *Getty Images*

OUR DESIRE TO FORM MEANINGFUL RELATIONSHIPS POWERFULLY INFLUENCES OUR INTERNAL MOTIVATION.

cantly more effort into learning. Work published in 2015 in the *Journal of Human Kinetics* by a Spanish team found that athletes' perception of how competent their coach thinks they are has more influence on self-image than the athlete's own perception of competence.

"The ability in a coach to build skills in their athletes and pass on new or helpful information is a really important aspect of coaching," says senior U.S. Olympic Committee sports psychologist Sean McCann, In other words, athletes want to feel that their competence is continually improving because of their coach's expertise. "I've seen this even at the national level: if athletes don't feel like they're learning something from a coach, it won't be an effective coach-player relationship."

It's All about the Relationship

It takes more than technical know-how to cultivate that relationship, however. Sports psychologist Jonathan Fader is a master. Visit him in his Manhattan office, and he will listen intently to what you have to say, respond thoughtfully and praise your accomplishments, but not before he eagerly invites you to play Ping-Pong on his transformable office table (the leaves retract to reveal paddles and balls). Ginsu-sharp, irreverent and magnetic, Fader embodies the kind of relatability that he espouses in his work with top athletes and coaches.

A long line of psychological, evolutionary and anthropological research supports Fader's emphasis on relatedness. It shows that our desire to form meaningful relationships powerfully influences our motivation. Work in the 1970s by psychologists Rosemarie Anderson, Sam Manoogian and J. Steven Reznick found that children given an engaging task in the presence of an adult who ignores them exhibit far less internal motivation than those in the presence of a responsive adult—call it "Hey, Mom, watch this!" with a bit of academic rigor. Similarly, in 1986 Ryan and psychologist Wendy S. Grolnick, now at Clark University, published a study showing that students who perceive their teachers as being cold and uncaring are significantly less motivated to learn and explore than their peers.

In recent years coaching research has uncovered a similar dynamic. A study by University of Wyoming sports psychologist Tucker Readdy, published this year in *Research Quarterly for Exercise and Sport,* used simple periodic interviewing to assess motivational influences in a small sample of cheerleaders. Both competence and relatedness with their teammates and coaches appeared to work synergistically to enhance motivation.

"Performance coaching is largely about relationship development and enhancing intrinsic motivation," Fader says. "We know that people who

ALEX LIVESEY *Getty Images*

Pia Sundhage, who coached the U.S. women's soccer team to Olympic gold in 2008 and 2012, enthusiastically joins players in practice and celebration.

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deliver information in an interactive and relationship-based way have the most success. If I can convey information to you in a way that allows you to participate in the information giving—for example, as with Socratic questioning or pulling from the person rather than just telling them what to do—you're likely to be more effective."

Yet, Fader believes, a surprising number of coaches do not get this. "I tend to mainly see screamers when I work in college athletics," he says. "You probably can't survive coaching like that at a big-league level. If you've gotten to a pro level and not realized the importance of creating relationships and focusing on the positives, your chances of success aren't nearly as good."

McCann concurs: "Relationship building is really essential if athlete and coach have to be around each other for more than a couple of years. There needs to be some level of mutual genuine respect."

Both psychologists emphasize that part of building a relationship is focusing on the positives, with McCann citing work from the 1990s by psychologists Ronald Smith and Frank Smoll of the University of Washington. Their findings support the so-called sandwich method of performance coaching, in which constructive criticism is bookended by praise. "If a kid misses a fly ball, say, 'Hey, good hustle, but remember you really got to keep your eye on the ball, but again good hustle,' " he explains, noting that the approach "increases motivation and the development of specific skills and decreases anxiety."

Fader agrees that this approach reduces shame and embarrassment that might result from overly harsh criticism. "If I'm going to talk to a quarterback or a pitcher and the first thing I bring up is what needs to changed, it's not going to work," he cautions. "The best coaches start by saying something positive. People need to feel like you're on their side before they're willing to accept what you're saying."

Bossy Coaching vs. Instilling Autonomy

The last component of self-determination theory—autonomy—is perhaps the best studied, at least in terms of assessing different coaching styles. In the 1960s American psychologist Richard DeCharms introduced the idea that competence alone is not enough to boost intrinsic motivation and that it must be accompanied by the perception of autonomy. This idea has since played out in a host of research that compares "autonomous-supportive" environments—in which people or players have a perceived control over their decisions and behaviors—and more "controlling" approaches in which those being coached simply follow orders.

Much of the early work in this area focused on how students learn. Several studies published in the 1980s, including some by self-determination theory developers Deci and Ryan, found that students' internal motivation and educational curiosity were stronger when teachers supported their autonomous efforts. Those under more strict control by teachers lost initiative and did not learn as effectively. This work also showed that children of controlling parents were less likely to spontaneously explore and attempt to master new skills.

The autonomous-supportive philosophy usually comes out on top in athletic coaching as well. A 2003 review by Geneviève A. Mageau and Robert J. Vallerand, both then at the University of Quebec at Montreal, published in the *Journal of Sports Sciences* looked at the impact on ath-

Pete Carroll, who led the Seattle Seahawks to two Super Bowls—and a 2014 victory—is known for encouraging players' individuality and autonomy.

OTTO GREULE, JR. *Getty Images*

"THE BEST COACHES START BY SAYING SOMETHING POSITIVE. PEOPLE NEED TO FEEL LIKE YOU'RE ON THEIR SIDE ... TO ACCEPT WHAT YOU'RE SAYING."
—Jonathan Fader

lete performance when coaches employed various autonomy-supportive behaviors, such as acknowledging their players' perspective, avoiding excessive controlling behaviors, and providing athletes choice and opportunities for independent initiative. These qualities were associated with greater intrinsic motivation in players, as measured by behavioral observation and self-report and, thus, by extrapolation a higher likelihood of success on the field. A 2015 study by Texas State University professor Lindsay E. Kipp, published in *Sport, Exercise, and Performance Psychology,* assessed the mental well-being of 174 adolescent female gymnasts using surveys that evaluated the three aspects of self-determination theory. Kipp found that an environment that supported autonomy predicted increased perception of competence among the athletes. Furthermore, higher perceived competence predicted greater self-esteem and fewer eating-disorder symptoms, to which young gymnasts are especially vulnerable.

From 2012 to 2013 Ken Hodge, a professor of sports and exercise psychology at the University of Otago in New Zealand, worked alongside the 2011 world champion All Blacks rugby team to study the effectiveness of various coaching strategies. He notes that a controlling environment can in some cases boost short-term performance—and help win a match here and there. Yet he concluded that authoritarian coaching—and the manipulation, shame and negative feedback that often come with it—can ultimately hinder winning and hurt player well-being.

"My research has shown that in the long term, using an autonomy-supportive leadership style does not compromise winning/performance and has added benefits in terms of personal development for players," Hodge says, likening this style to that of one of his favorite big-name coaches, Pete Carroll of the Seattle Seahawks. In a 2014 player poll, Carroll was voted the most popular coach in the National Football League. The coach, who led his team to a 2014 Super Bowl victory and a near repeat win the year after, is known around the league as being unusually supportive of individual player opinions and personalities. He encourages loud music in the locker room. His team meetings often involve a game of mini basketball. When he reviews video of past games with his players, he tends to focus on wins, not losses. "That sounds an awful lot like autonomy-supportive coaching to me," Hodge says.

The *New* Coaching

Whether intentionally or not, many if not most successful coaches employ elements of self-determination theory. As evidence builds supporting the philosophy—and discrediting authoritarian approaches—more coaches will likely get on board.

"I really think the theory has contributed greatly to sports psychology," Michigan State's Gould says. "I try to get coaches to identify specific ways they can meet athlete autonomy, competence and relatedness. My experience is that great leaders know how to build strong coach-athlete relationships, which is a key to leadership effectiveness."

None of this is to say that coaches should go soft. Individual coaches must find their own approach, Gould says, and adapt it to their given roster of athletes. A variety of coaching styles will surely be on display at the Olympic Games in Rio. That will likely include some gruff demeanors and letting loose with some well-timed tirades. Even Coach K, for all his social nuance, loses his cool every now and again. M

MORE TO EXPLORE

- **Connecting Athletes' Self-Perceptions and Metaperceptions of Competence: A Structural Equation Modeling Approach.** Jose A. Cecchini, Javier Fernández-Rio and Antonio Méndez-Giménez in *Journal of Human Kinetics,* Vol. 46, pages 189–198; June 27, 2015.
- **Social Predictors of Psychological Need Satisfaction and Well-Being among Female Adolescent Gymnasts: A Longitudinal Analysis.** Lindsay E. Kipp and Maureen R. Weiss in *Sport, Exercise, and Performance Psychology,* Vol. 4, No. 3, pages 153–169; August 2015.
- **Ultimately It Comes Down to the Relationship: Experienced Consultants' Views of Effective Sport Psychology Consulting.** Lee-Ann Sharp et al. in *The Sport Psychologist,* Vol. 29, No. 4, pages 358–370; December 2015.
- **A Qualitative Investigation of Need Fulfillment and Motivational Profiles in Collegiate Cheerleading.** Johannes Raabe and Tucker Readdy in *Research Quarterly for Exercise and Sport,* Vol. 87, No. 1, pages 78–88; 2016.

From Our Archives

- **Avoiding the Big Choke.** Elizabeth Svoboda; February/March 2009.

OVER IND EAT

We love animals, yet most of us also eat them. Research is revealing the cognitive tricks we use to resolve this omnivore's dilemma

By Marta Zaraska

GETTY IMAGES

Consider the pig. Perhaps your mouth is already watering at the thought of crispy bacon, juicy ribs, savory ham and spicy sausage. The United Nations Food and Agriculture Organization reports that people eat pork in more places worldwide than any other meat, with it making up 36 percent of all carnivorous consumption. Americans consume about 50 pounds per person every year—and that is nothing compared with China, where people eat twice as much.

But in some communities, pig meat is untouchable. Consumption is banned by both Islam and Judaism. And some people regard pigs—particularly the diminutive potbelly variety—as adorable pets. Remarkably social and much cleaner than their reputations suggest, pigs are very intelligent. Savvy swine play chase, operate

thermostats in their pens and can even learn simple computer games. A 2014 study in *Animal Cognition* revealed that pigs could understand pointing cues from humans in a way similar to what dogs do.

If at this point you are starting to feel a little uneasy about your BLT, you are not alone. This discomfort stems from a phenomenon that scientists have dubbed "the meat paradox." It comes about when people like to eat meat but do not like to think of animals dying to provide it. "If you scratch the surface, everybody seems to be a bit uncomfortable about eating meat," explains Brock Bastian, a psychologist at the University of Melbourne in Australia. Fundamentally, if you like all creatures great and small, the idea of causing them harm is at least a little disturbing. "One of the most deeply and widely held moral concerns is to prevent harm," Bastian says. "If an animal died of natural causes, I doubt that people would feel conflict over eating it."

The more someone likes meat and likes animals, the more pronounced the problem becomes. The perception that you can be an animal lover and an animal eater at the same time is ubiquitous; it drives the cage-free, free-range movement in the modern meat industry. In one study, 81 percent of Ohioans said that the well-being of farm animals is just as important to them as the well-being of pets. Americans spend fortunes on their furry friends: in 2015 an estimated $60 billion. Yet that does not stop them from consuming about nine billion animals per year.

The meat paradox is an avenue for understanding cognitive dissonance, a psychologically unpleasant state that arises when we hold dear several mutually inconsistent beliefs or when there is a gap between our attitudes and our behavior. Stanford University psychologist Leon Festinger first described the concept back in 1957. But the meat paradox is a more recent area of study. The paradox has shifted into focus as psychologists investigate the ways in which we frame our appetite for animals. What they have uncovered is that we use a variety of cognitive tricks to distinguish animals that we consume from those we do not in order to make unpalatable ideas easier to swallow.

Culture and Camouflage

Ask people why they eat meat, and certain responses will come up over and over again. Among the most common are what psychologist Matthew Ruby of the University of Pennsylvania calls "the 4Ns." In a 2015 paper published in the journal *Appetite,* Ruby, along with an international team of collaborators, enumerated the four: we justify consumption of animals with the beliefs that meat eating is natural (we evolved to eat meat), normal (everybody does it), necessary (we need the protein) and nice (it tastes good).

There is some truth to each of these points—but the fact that vegetarian societies exist shows that the 4Ns have their limits. Confounding the issue, many people who believe in the 4Ns, according to Ruby, also exhibit confirmation bias, or the tendency to favor information that reinforces beliefs we already hold. (Another example comes from heavy smokers who, studies demonstrate, are less likely to believe reports linking cigarettes to lung cancer.) In the field of meat eating, economists Ying Cao, now at the University of Guelph in Ontario, and David Just of Cornell University found that among people who received information on the risks of getting food poisoning from beef, those who had just consumed the meat were more likely to discredit the news than those who had dined on salmon. "This sort of confirmation bias plays a significant role in making meat-based diets plausible," Just explains.

On a deeper level, culture is crucial in understanding why we permit some animals in our home but put others on our plate. In some societies, eating dogs is a no-no, whereas consuming cows is perfectly fine. In others, it is taboo to eat cows, pigs or even chickens, which are regarded as unclean in Tibet because of their worm-based diet. Anthropologists such as Frederick Simoons and Marvin Harris long argued that whether we consider an animal "meat" boils down to its past economic relevance (for example, a horse that could plow fields would not be eaten) and its usefulness as a marker of tribal identity (as in Africa, where different clans and subclans observe different dietary restrictions to distinguish themselves).

Once a community categorizes an animal as "food," it changes the way we consider these creatures. In 2011 Bastian, along with psychologists Steve Laughnan, then at the University of Kent in England, and Boyka Bratanova, then at the University of Surrey in England, asked 80 volunteers to read a short paragraph about Bennett's tree kangaroos, which are native to Australia. Some of the participants encountered a version of the story in which locals regularly ate the animals, and others read general information about the kangaroos that omitted any mention of them as food. When the participants rated how much the kangaroo would suffer if harmed, clear differences emerged. People who had not read that tree kangaroos are considered food indicated their capacity to suffer as a nine out of 10, whereas those who read that the animals are often eaten judged it lower—close to a seven.

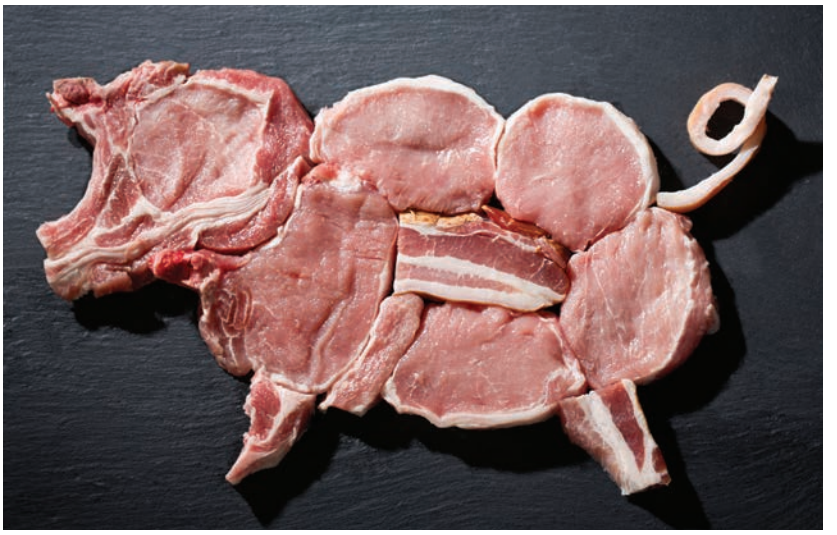
We further obscure the connection between a sentient creature and possible food source through what psychologists term "linguistic camouflaging." "We don't call the meat the actual name of the animal. We call it pork and beef and bacon," explains Hank Rothgerber, a psychologist at Bellarmine University in Louisville. And modern English speakers are certainly not the only

FAST FACTS

THE MEAT PARADOX

1. Psychologists have found that people who eat animals but also love them and do not want them to be hurt experience cognitive dissonance, or a state of tension created by holding or acting on mutually inconsistent beliefs.
2. Although the simplest route to conquering this dissonance would be realigning attitudes and behavior, vegetarianism is relatively rare, suggesting most animal lovers find other ways to respond.
3. Tactics such as avoidance, dissociation and perceived behavioral change enable many people to get past their psychological distress and eat a meaty meal.

Linguistic camouflaging conceals the animals we eat (pig meat, for example, becomes "pork"). In 18th-century Japan, horse meat was called "cherry," deer "maple" and wild boar "peony."



ones to engage in such linguistic camouflaging: in 18th-century Japan people went so far as to rename horse meat "cherry," deer "maple" and wild boar "peony."

Dissociation and Depersonalization

The surest way to conquer cognitive dissonance is to resolve the disparity between what you think and how you act. In the event that you adore animals and cannot stand to think of them sent to the slaughterhouse, vegetarianism would certainly do the trick. Yet judging from the low numbers of vegetarians (between 3 and 5 percent of the population in the U.S.), that is not a technique most people choose. Perhaps unsurprisingly, those people who do quit carnivorous habits may have a heightened sensitivity to animal suffering. In 2010 neurologist Massimo Filippi of Scientific Institute and University Hospital San Raffaele in Milan, Italy, and his colleagues presented 60 volunteers images either of landscapes or of humans and animals in pain while examining their brain activity with functional magnetic resonance imaging. "Our results showed a different pattern of activations between omnivores and vegetarians while observing animal scenes, with a higher engagement of empathy-related areas, such as the anterior cingulate cortex, in the vegetarian group," Filippi says.

Rather than breaking completely from steak dinners and tuna salads, far more people opt for what scientists call "perceived behavioral change." This is generally a partial solution to the paradox that gives a person peace of mind. Someone who loves animals but is disturbed by the conditions on factory farms may buy meat from butchers who promise their animals were raised and slaughtered humanely. Perceived behavioral change can also include people who are trying to convince themselves and others that they have stopped eating meat—even if it is not true. In a study published in 2015 and based on the data from the U.S. Department of Agriculture and the National Health and Nutrition Examination Survey, for instance, a staggering 27 percent of "vegetarians" admitted to eating red meat.

Another solution to the meat paradox is avoidance. "That's the primary strategy—not to think about the origin of meat at all," Rothgerber says. In 2014 he and Frances Mican, a student collaborator at that time, showed that people who were strongly attached to their childhood pets were even more inclined than the rest of us to avoid contemplating where meat actually comes from.

The next cognitive dissonance–reducing option is dissociation. By somehow separating the animals we eat from their animalness, we can think of them, in effect, as merely meat. This tendency can help explain linguistic camouflage and the ways in which we try to create mental distance between an animal capable of thought and a possible source of food. The latter also explains why many of us tend to think of the animals we eat as less intelligent than our pet dogs and cats.

In 2012 Ruby, along with psychologist Steven Heine of the University of British Columbia, distributed two versions of a survey among 608 omnivores. In one version, people rated the food-related attributes (for example, how likely they would be to eat a given animal) of 17 creatures, such as chickens, cows and dogs. Afterward, they had to estimate the intelligence and emotions of the animals. In the second version of the survey, the tasks were reversed; participants had to think about the inner lives of the animals before contemplating their edibleness. The result was not surprising: thinking about an animal's mental capacity first made people feel more repelled by the idea of eating its meat.

The pattern crystallized in a 2012 study by Bastian, then at the University of Queensland in Australia, and his col-

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GETTY IMAGES

STRICTLY TABOO?

What we eat and what we reject varies enormously from one culture to the next. Strong taboos develop for a variety of reasons: spiritual, practical, economic and social. Here is a sampling of what is and isn't on the table at various spots around the world. *—Jordana Cepelewicz*

Animal	Who Eats It	Who Does Not and Why
Cat	News reports suggest that millions of cats are eaten annually in China. In Cameroon, dining on cat meat is thought to bring good luck. According to a Swiss animal-rights group, some farmers in rural Switzerland still eat domestic cats.	Around the world people keep cats as pets and often treat them as members of the family, making it taboo, on moral grounds, to kill or eat them.
Chicken	A popular part of the global diet, it accounts for 31 percent of humanity's meat consumption.	Among some groups in Africa and Asia, eating chicken is prohibited because the bird is thought to be prophetic. Its bones are often used in divination and sacrificial rituals. Meanwhile some Indian and Tibetan cooks see the animal as unclean.
Cow	Beef is among the most widely consumed meats by people the world over, coming in just behind pork and poultry.	Not permitted to followers of Hinduism, who consider the cow a sacred animal.
Dog	Eaten in parts of East and Southeast Asia, including Vietnam and South Korea—although the practice is in decline. People in Yulin in China's Guangxi Zhuangzu region celebrate the summer solstice with a controversial dog-eating festival when some 10,000 canines are killed. The meat is thought to bring good luck and health.	Westerners see dogs as "man's best friend." Often anthropomorphized, the animal is viewed as a beloved pet and family member, which puts eating it off-limits. In countries where people traditionally eat dog meat, a recent increase in pet dog ownership corresponds to a drop in the popularity of its meat.
Grasshopper	A delicacy in Mexico and Uganda. Like many other insects, it is an excellent source of protein (arguably better than chicken).	Insects are unpopular in many Western nations, including the U.S., where they are seen as unpalatable.
Horse	Eaten in several European and Asian countries, including France, Belgium, Germany and Kazakhstan. High in protein and low in fat content, horse meat is often considered a delicacy.	People eschew horse meat in the U.S., Ireland and the U.K., where horses tend to be seen as companion animals or pets. Economic factors may contribute: historically, people got more bang for their buck raising a horse for, say, transportation rather than for food. Some scholars assert that horse meat, associated with pagan rituals, fell out of favor when Christianity spread throughout sixth-century Britain.
Pig	Consumed by people around the globe. United Nations data show that it is the world's most widely eaten meat.	Forbidden to adherents of Islam and Judaism. Many historians attribute this religious restriction to the view that pigs were "unclean" carriers of disease or to the fact that pigs were difficult to raise in the Middle East, where the taboo originated.

leagues. The team showed 128 meat eaters a picture of a cow or a sheep and asked each person to rate the animal's mental capacities, such as its ability to experience pleasure, fear or rage. Then participants attended a supposedly separate "consumer behavior study," which involved composing an essay on the origins of beef or lamb. As the volunteers were about to start writing, the scientists placed a plate heaped with food in front of them. Some got apples; others got roast beef or lamb "infused with rosemary and garlic" to sample later. Once the essays were finished, the volunteers had to again rate the smarts of a cow or a sheep before they could dig into the food.

Analyzing the results, Bastian and his colleagues noticed that people changed their judgment of the animal's mind if they thought they were just about to eat meat. "This experiment really nails the dissonance process: if you want to eat meat, then changing your perception of a cow as being less morally relevant will resolve your dissonance," Bastian says. He also found that the more people denied attribution of mind to a cow or a sheep, the less negative emotion they experienced when faced with the prospect of eating it.

On the flip side, other researchers have found that encouraging people to think about an animal's humanlike traits, such as whether or not a dog could be a good listener, will make people less inclined to think of animals as food. And yet another Bastian study from 2011 found that people asked to write an essay on "What makes animals similar to humans?" were less okay with the idea of raising cattle or chickens for meat than people who wrote essays on "What makes humans similar to animals?" Clearly, we think of other creatures more highly if we compare them with ourselves—but the reverse is not true.

Even the sheer number of animals butchered for meat may depersonalize animals, creating greater distance between them and us. Experiments suggest that the greater the number of victims in an accident or a natural disaster, for example, the less personal connection people feel to their suffering. In one classic study, people donated more than twice as much to an identifiable victim

("Baby Jessica") than to statistical victims (10,000 children).

In 2013 researchers at Carnegie Mellon University, the University of Michigan, Ohio State University and the University of California, Santa Barbara, conducted a similar experiment. They divided 97 volunteers into groups, showed them images of sea creatures, and asked them to rate the extent to which the animals could experience beliefs or desires. But there was a catch. Some people evaluated a sea creature surrounded by plenty of look-alikes of the same color, and remaining volunteers had to rate a creature swimming among others of a contrasting color. The unique animal was thought to be smarter than the clones. "Our findings suggest that the large number of animals living on industrial farms may reduce our attribution of mind to those animals when we consider whether to eat them, which should increase its acceptability," says the study's lead author, psychologist Carey Morewedge, now at Boston University.

Gender shapes how we resolve the paradox. Men are more likely to doubt animals feel emotions; women often opt to dissociate animals from food.

What is more, men and women use different techniques to reduce the dissonance caused by the meat paradox. A 2014 study showed, for example, that men are more likely than women to doubt that animals can experience such complex emotions as love or grief. They are also more inclined than women to use what scientists call "pro-meat justifications" such as the 4Ns. Meanwhile, according to Rothgerber, women opt for dissociation—they simply look the other way.

The reason for such differences, Rothgerber believes, boils down to our cultural assumption that meat is somehow a manly food. "By eating meat, men obtain validation of their identity. They are actually rewarded for thinking about it," he says. Indeed, a 2012 experiment at the University of Pennsylvania found that most students saw steaks, hamburgers and beef chili as "male" foods; "female" foods included chocolate and peaches.

Minding Your Meals

The unpleasant condition of cognitive dissonance can also explain why having omnivores and vegetarians at one dinner table may result in awkward feelings. It appears that the presence of people with differing dietary habits puts the meat paradox in the spotlight. Things can even get awkward between the two types of vegetarians: ethical vegetarians (those who went "veg" for the health of the chickens, not their own—to borrow from Isaac Bashevis Singer) and health vegetarians. In 2014 Rothgerber found that ethical vegetarians judge health vegetarians less favorably after they are prompted to think about meat eaters. Cognitive dissonance also has a way of making people defensive: a 2010 experiment showed that people who doubt their choice of diet advocate in its favor more fervently than those who feel confident about it.

Despite the discomfort, confronting the paradox can be a useful exercise if we want to make more conscious choices about food. "If we were more aware of the mental backflips we do to be able to eat animals, if we could admit to ourselves that we are uncomfortable about it, we could make more informed decisions on whether we want to eat meat or not," Bastian says. A meat eater himself, Bastian is one of several scientists in this field who are motivated by concern that the growing global appetite for meat is unsustainable from an environmental perspective while also raising ethical and health concerns. Meat eating, after all, is responsible for more greenhouse gas emissions than driving cars, and most of the demand is met by factory farms, which are among the worst emissions offenders. Meanwhile several studies have connected eating red meat to heart disease, and according to a 2015 study in the *Lancet,* processed meats such as sausage and bacon are linked to a greater risk of cancer.

Within the field of psychology, the meat paradox belongs to a burgeoning area of investigation into our tendency to ascribe mental properties to entities all around us. In 2008, for example, University of Chicago psychologist John Cacioppo and his colleagues found that lonely people are more likely to anthropomorphize pets than more socially satisfied individuals. Many people even attribute human properties to inanimate objects, for instance, by naming a beloved pair of shoes or a trusty old car.

The meat paradox, however, adds a new dimension to that research. Although many findings have shown how easily we *give* minds to the beings or objects around us, manipulations concerning the meat we eat show that we also take this mental gift away—even when we know that the creature involved is capable of learning and sensation. In other words, we bestow "mind" on others as a matter of personal convenience. If nothing else, this aspect of human nature can provide some toothy food for thought. M

MORE TO EXPLORE

- **Who's Lying about Not Eating Meat?** Hal Herzog in *Psychology Today.* Published online August 8, 2014. **www.psychologytoday.com/blog/animals-and-us/201408/whos-lying-about-not-eating-meat**
- **Can You Have Your Meat and Eat It Too? Conscientious Omnivores, Vegetarians, and Adherence to Diet.** Hank Rothgerber in *Appetite,* Vol. 84, pages 196–203; January 1, 2015.
- **Know Your Pork—Or Better Don't: Debating Animal Minds in the Context of the Meat Paradox.** J. Benz-Schwarzburg and C. Nawroth in *Know Your Food.* Edited by Diana Elena Dumitras, Ionel Mugurel Jitea and Stef Aerts. Wageningen Academic Publishers, 2015.
- Video of Brock Bastian's presentation at the 2014 seminar Voiceless Rethinking: Speciesism: **www.youtube.com/watch?v=INu5VsBFBXk**

From Our Archives

- **The Carnivore's Dilemma.** Morgan E. Peck; Head Lines, March/April 2012.
- **Pets: Why Do We Have Them?** Daisy Yuhas; May/June 2015.

OUT OF THE SHADOWS

The way we detect shape and depth from shading reveals some primeval rules that govern how we see the world

By Chaipat Chunharas and Vilayanur S. Ramachandran

Our perception of the world seems so effortless that we take it for granted. But think of what is involved when you look at even the simplest visual scene. You are given two tiny, upside-down images in your eyeballs, yet what you see is a unified three-dimensional world. This phenomenon, as the late neuropsychologist Richard Gregory once said, is "nothing short of a miracle."

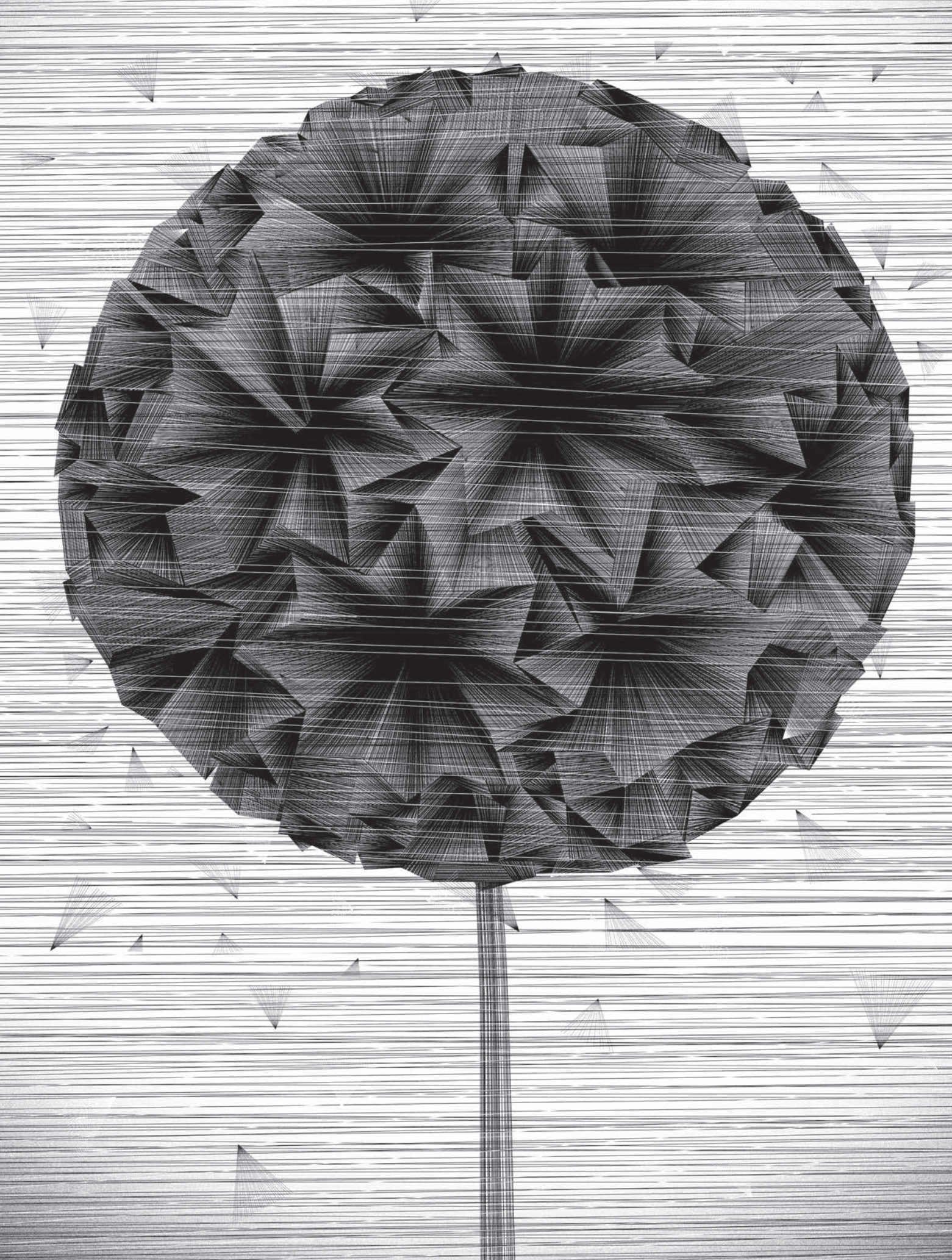
In practice, this "miraculous" process involves our brain making use of a number of different cues. These can include occlusion (if A covers some part of B, A must be in front), motion parallax (in which objects closer to us appear to move faster than those farther away) and shapes discerned from shading—the main topic of this article. Far from being a mere device employed by artists to convey the impression of depth, shading is a powerful source of information about the 3-D layout of the external world. This information is extracted by using a compact set of simple rules that we have been investigating in our laboratory.

As perception scientists, we study unconscious assumptions that people make about the world and the manner in which the brain uses those ideas to predict what it will encounter in the world. To do so, we work in parallel with a number of vision scientist colleagues, including Heinrich H. Bülthoff of the Max Planck Institute for Biological Cybernetics in Tübingen, Germany, Daniel J. Kersten of the University of Minnesota, James Todd of Ohio State University and Patrick Cavanagh of Harvard University. Together we aim to uncover the perceptual rules that enable the resolution of ambiguity when interpreting shapes from shading and to explore the stages of cognitive processing involved. Such investigations can provide insight into the "rules" used by the brain in perceiving the world, many of which reflect our evolutionary history.

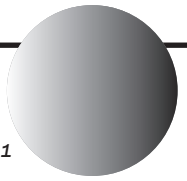
There are not many areas of science in which you can spend just a few hours doodling on your laptop and make surprising new observations in a field that is more than 150 years old. In most scientific disciplines, such as physics or chemistry, the goal is to describe laws that are "objective," in that they deliberately exclude the subjectivity of the observer. The study of perception is unique in the sense that the object *is* the subject, which gives the enterprise a curious recursive quality. Thus, the demonstrations that follow are each a unique experiment in which you the reader can participate.

It should be noted that our informal observations need to be followed up with careful measurements and that many questions remain to be answered. But we hope to convince readers that visual illusions are more than amusing curiosities. They allow us to measure the "IQ" of the visual system. Its processing strategies are often surprisingly sophisticated, but equally often it uses heuristics and shortcuts.

ILLUSTRATION BY *Kai & Sunny*
DIAGRAMS BY *Chaipat Chunharas and Vilayanur S. Ramachandran*



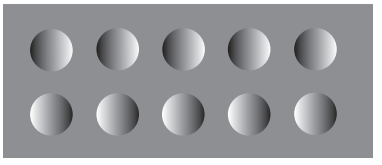
The Basic Rules of Shading



1

Consider a simple circle with a gradient suggesting one side is illuminated and the other is in shadow (*1*). Such an illustration is usually seen as a sphere or ball lit from the left, although with a bit of effort you can see it as a cavity lit from the right. This demonstration uncovers the first rule of shape from shading: other things being equal, convexity is preferable. We may have this preference because the objects we encounter in nature are usually convex. A creature that has evolved on Venus, which has no solid objects, would not show this preference.

Now examine the illustration at the right (*2*), and you will notice something strange: when the top row is seen as spheres, there is a strong tendency to see the bottom row as cavities, and vice versa. This observation demonstrates the single-light-source rule, the assumption that in interpreting shaded images, the brain assumes that the entire scene is illuminated by a single light source. You never see the top and bottom rows as both convex and being illuminated from opposite directions. This particular bias makes sense, given that our planet has a single sun.

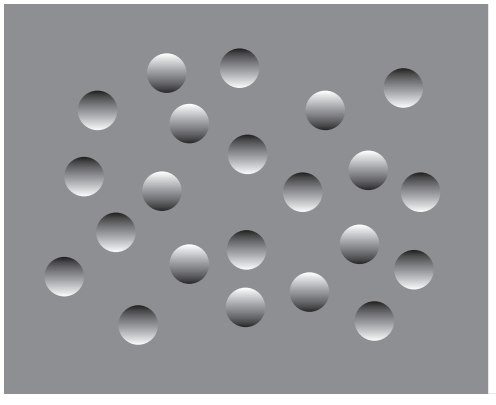


2

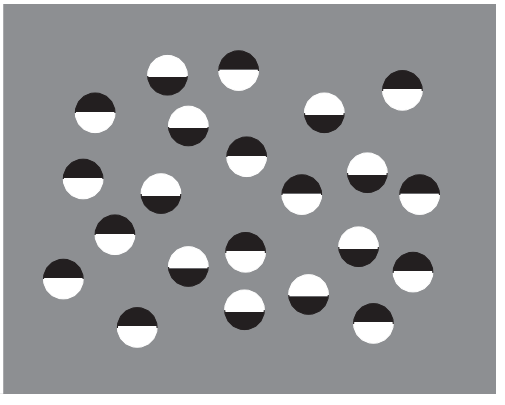
Next look at *3a*. Notice that the disks that are light on top invariably look like spheres, whereas the ones that are light below look like cavities. This demonstrates the third principle: the brain assumes that, in addition to having only one light source, the source must be shining from above (again this is because the sun shines from above, not below). Scottish physicist Sir David Brewster noticed this overhead lighting bias more than 100 years ago when viewing cameos lit from different directions. Our multiple shaded disks amplify the effect considerably and strip the illusion down to its bare essentials.

Perception does not involve faithfully transmitting the retinal image to the visual areas of the brain. The process is more complex. Different attributes in the image—called elementary features—are extracted by neurons early in visual processing before activating a cascade of events that culminates in your final act of perception. Examples of such features include edges (especially their orientation), motion and color, all of which are extracted early—quite possibly in area 17, the first visual-processing area of the brain's cortex. More complex features such as facial expression, on the other hand, are computed much later in the process.

One characteristic of elementary features is the fact that they segregate clearly into different groups even when they are intermixed. Shading follows this pattern. Most people viewing *3a,* for example, can effortlessly group the spheres and segregate them from the cavities. But the same cannot be said for *3b*. This comparison suggests that shading—but not the mere variation of light intensity (known as luminance) across disks—is probably an elementary feature extracted early in the processing stream. Indeed, in 1997 a team of researchers at the University of Western Ontario confirmed our speculation that shading is extracted early in visual processing by measuring the brain activity of six observers using functional magnetic resonance imaging.



3a



3b

But how does the brain put together different depth cues to construct a holistic three-dimensional representation of the world? As discussed, there are many different sources of information about depth, so it stands to reason that the brain initially handles each of these features independently. Is it possible that the signals from different depth cues converge onto a master depth map farther up in the brain?

The answer can be seen in *4*. Even on casual inspection, it is obvious that segregation is powerful in *4b* but far less vivid in *4a*—in other words, it is much easier to perceive different planes of disks in *4b*. In *4a,* the thin horizontal lines cover the spheres and run behind the cavities, which feels wrong because

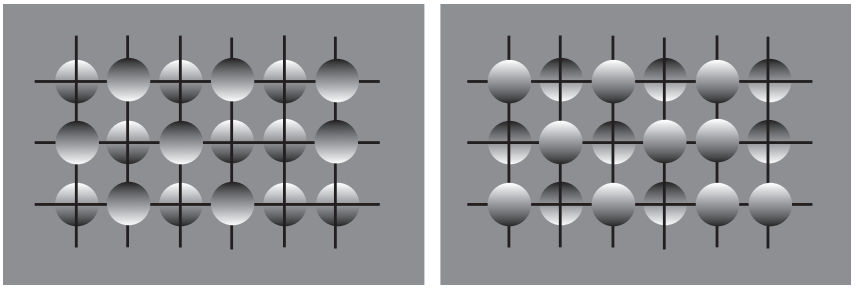
FAST FACTS

SHAPE FROM SHADING

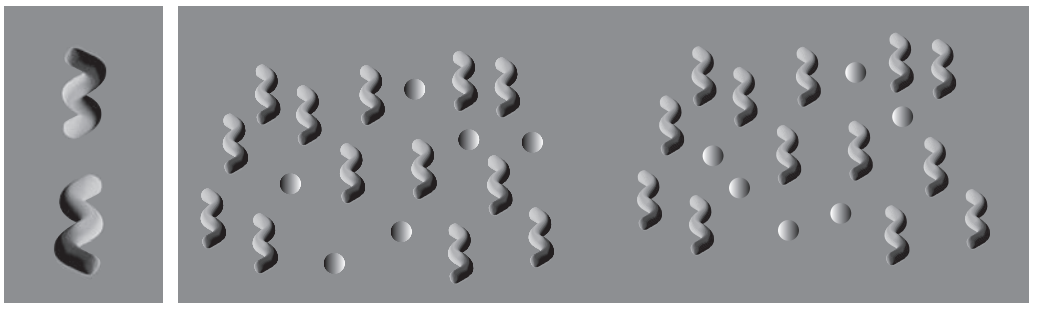
1. A number of basic rules based on our evolutionary history influence how we interpret shadows and shading.
2. Shading is one of several elementary features that our brain's perceptual system extracts early in visual processing.
3. The same biases and shortcuts that allow us to rapidly assess depth in a two-dimensional image can also lead to misunderstandings such as illusory movement.

we expect concave cavities to fall *behind* convex spheres. What these illustrations reveal is that our brain looks for consistency when combining cues to construct a 3-D reality—otherwise we would not detect this dissonance.

The next question is, How does the visual system "know" where the light is coming from? To solve this puzzle, we created vertical "worms," which always appear juicy and never concave in this illustration (*5a*). Simple, shaded disks, however, are more ambiguous (as we have established, they become convex or concave based on our assumptions about lighting). When we disperse these disks among the worms in the rightmost illustration (*5b*), they tend to be seen as convex to conform to the light source from the left, as implied by the worms. (The reverse occurs in the left part of this demonstration.) The brain is therefore using the presence of unambiguous objects—our worms—to decipher where light is coming from and then interpret the more ambiguous details of an image.



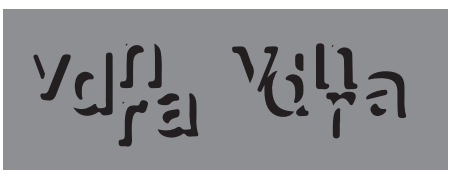
4a *4b*



5a *5b*

Shapes and Shadows

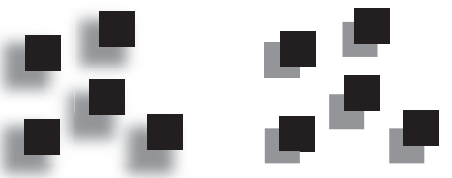
Our next display (*6a* and *6b*) is yet another demonstration of the constraint of the single light source. But this time we use shadow rather than shading. In *6a*, what are initially seen as random black fragments soon crystallize into 3-D letters of the alphabet. In *6b*, on the other hand, the same letters are harder to perceive as 3-D because they are randomly lit from below left or above right. This is true despite the fact that one can cognitively infer the letters individually. The difference is especially clear if the alphabet clusters are viewed in a holistic manner. The effect is also amplified if you tilt any edge of the paper by more than 60 degrees.



6a *6b*

In the previous illustration, the 3-D letters have what are called attached shadows, in which shading appears on an object. We now turn to what graphic designers and artists use intuitively: cast shadows, which are not attached to their source (*7a* and *7b*). Our next question is, How intelligent are the systems that our brain relies on to determine depth using shadows?

First notice that shadows with penumbrae—the softer-edged shading in *7a*—are more realistic than those with sharp edges, such as *7b*. German physiologist Ewald Hering made this observation in the 19th century. In *7*, you can see that even though the shadow area is located at the same distance from the square in both *7a* and *7b*, the squares with blurred-edged shadows appear nearer to the observer than those with sharp-edged shadows.



7a *7b*

The next illustration shows that the distance between the

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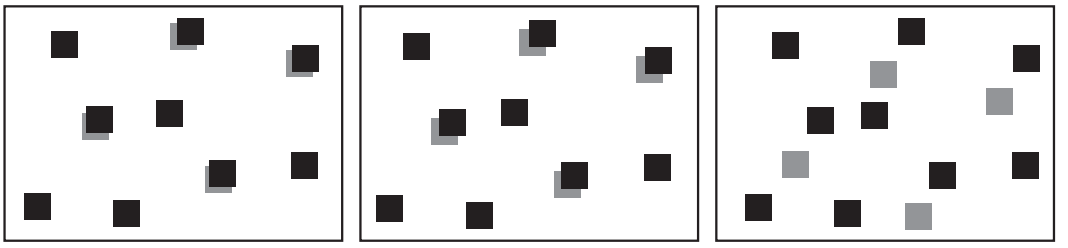
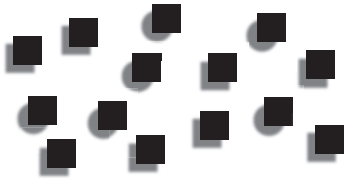


8a 8b 8c

square and the shadow matters (compare *8a* and *8b*). The shadows can signal not only the presence but also the magnitude of depth. Yet this is no longer true if the shadow is completely detached from the object (*8c*). Even though this happens in the real world, it does not happen often enough to be incorporated, as a rule of thumb, into visual processing.

When the Systems Fail

There are limits to how sophisticated our perception truly is. We observe that the shape of a shadow does not inhibit our ability to link an object to its shadow (*9*). The system is smart but clearly not smart enough. More intensive investigation might reveal limits to this tolerance of shape mismatch between a shadow and its source.

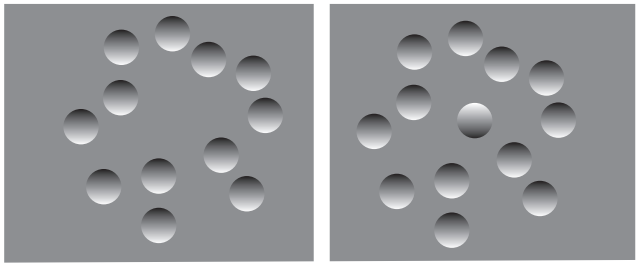


9

Another example of our perceptual limits comes from considering how some rules may overturn others. In addition to the constraints of having a single light source and light above, for example, there is a weaker assumption that a single, isolated shaded disk is most likely to be convex even when lit from below (rather than a cavity lit from above). This effect is especially true when multiple disks are used, and most naive subjects—as a default—see them as a clutch of spheres (*10a*).

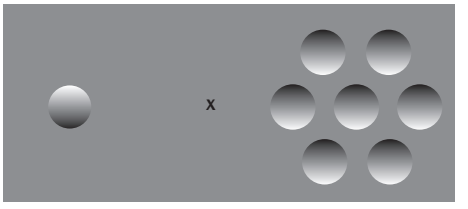
Yet if a single sphere lit from above is inserted among them (*10b*), the other disks instantly transform into cavities because of the new information provided by the single sphere. This change is a striking example of how a single but strong cue can veto the effect of multiple ambiguous inputs.

The important role of attention in light-source interpretation can be seen in the next illustration. If you fixate on the "X" in the middle of the display in *11* and focus your attention on just the cluster on the right, you will see it is made of spheres (lit from below). But if you let your attention expand to include the single sphere on the left, instantly the disks on the right start to look like cavities. We may conclude that the light-source rule applies not to the entire visual field but only to the portion that is encompassed by the window of attention.



10a 10b

By conveying depth using other cues, we can discover new ways to test our perceptual intelligence. Although different aspects of the visual image (such as color and shading) are initially extracted by separate neural channels early in visual processing, they are eventually put together to form a coherent object or event in the visual scene. We have begun doing experiments to explore how the different sources of information interact.

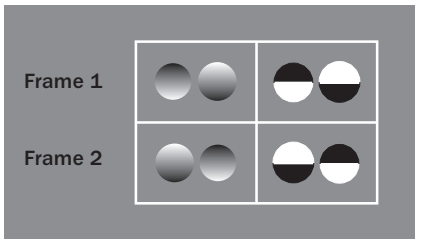


11

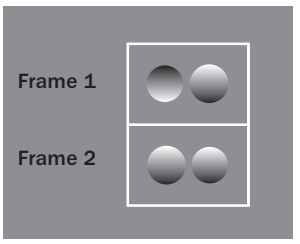
In an unpublished study, we investigated the interaction between shading and movement by creating an animation using the two frames shown in *12a*. A sphere and a cavity were presented simultaneously, side by side, in frame 1 of the movie sequence. This was followed by the sphere and cavity appearing in the reversed locations in frame 2. In our demonstration, the two frames cycled continuously. Theoretically, there were at least three ways in which one could see the display:

1. Two flat, shaded disks reversing the polarity (direction) of luminance.
2. A stationary sphere transforming into a cavity on the left, while a cavity transforms into a sphere on the right.
3. The sphere and cavity trading places.

What more than two thirds of our 15 participants actually saw was something completely different and unexpected: a single ball jumping left and right—filling and emptying two stationary cavities in the background! In the control setup, which did



12a



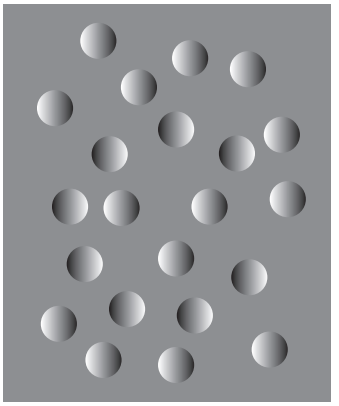
12b

To see the animation, visit ScientificAmerican.com/shadinginmotion

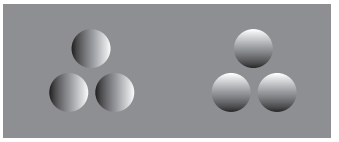
not employ a shading gradient (*12a, rightmost panels*), people did not see any such movement. This experiment demonstrates that the visual system, even early in processing, deploys surprisingly sophisticated knowledge about moving objects—namely that in the real world, cavities do not move, but balls or spheres do.

Remarkably the entire perception of the display changes if the lighting is reversed for only one disk and not the other (*12b*). This time the disk on the left is seen to pulse inward and outward, morphing between sphere and cavity. The brain is willing to accept the deforming sphere, in the interest of obeying the single-light-source rule.

On the other hand, if there is no overhead lighting, the visual system reverts to the single-light-source rule, as shown in *13*. Here half the disks are left-right shaded, and half are shaded from right to left.



13



14

Now have someone hold the page upright in relation to gravity (as most people would naturally do to read the words on the page) while you tilt your head sideways 90 degrees so that it is parallel with the ground. (You might find it easier if you lie down on your side.) You will discover that half the disks—the ones lit on the left—suddenly transform into spectacular spheres and the rest into cavities. So "light above" refers to "above" in relation to the head rather than the world!

Although you, as the conscious observer, know the sun is still overhead, your visual system, which is on autopilot, does not know. It makes the silly assumption that the sun is still above—as though it were stuck to your head—even when your head tilts, probably because our ancestors did not walk around with their head to the side often enough to require a mechanism that would correct for this tilt using vestibular feedback. The computational burden of doing so was avoided altogether by using a quick and dirty shortcut. The penalty you pay is vulnerability to false interpretation—your ancestors may have seen concave oranges when their head tilted accidentally. But so long as people could continue surviving long enough to have babies, this cost was not an issue in evolutionary terms.

So how does the brain get away with using such shortcuts? The goal of evolution is adequacy—not optimality—and scientists working in AI, robotics and computer vision would do well to follow nature's footsteps. As our colleague Francis Crick said, "God is a hacker."

Whenever our brain missteps and we perceive something incorrectly, we are experiencing an illusion. Such demonstrations also have an aesthetic component, not just because they are appealing visually but also because the researcher's scientific inference is based directly on observation. (Our observations are therefore not many steps removed from the data, as is often the case in other areas of science.) There is beauty in working so closely with nature.

Finally, these illusions have implications for other aspects of vision beyond depth perception. For example, our studies provide insight into how we perceive lightness and brightness. Consider the trio of left-right shaded disks compared with three top-lit spheres in *14*. This demonstration provides insight into the phenomenon of seeing the steepness of the luminance gradient—that is, the perceived contrast of brightness from one side of a disk to the other. Despite the fact that these shapes are physically identical, you probably see greater contrast in the left-right shaded set. We perceive a difference because—given the overhead-lighting rule—the top-lit spheres appear to bulge out more, and the visual system ascribes the lion's share of light intensity to surface curvature. In the case of left-right shaded disks, the brain attributes the difference in luminance to the surface itself, a principle called reflectance.

Using such demonstrations, one can play Sherlock Holmes to unravel perception's mysteries. We invite readers to create their own images and then write to us at vramacha@ucsd.edu or cchunharas@ucsd.edu about their discoveries. **M**

MORE TO EXPLORE

- **Perception of Shape from Shading.** V. S. Ramachandran in *Nature,* Vol. 331, pages 163–166; January 1988.
- **On the Perception of Shape from Shading.** Dorothy A. Kleffner and V. S. Ramachandran in *Perception & Psychophysics,* Vol. 52, No. 1, pages 18–36; July 1992.
- **The Extraction of 3D Shape from Texture and Shading in the Human Brain.** S. S. Georgieva et al. in *Cerebral Cortex,* Vol. 18, No. 10, pages 2416–2438; 2008.

From Our Archives

- **Perceiving Shape from Shading.** Vilayanur S. Ramachandran; *Scientific American,* August 1988.
- **Seeing Is Believing.** Vilayanur S. Ramachandran and Diane Rogers-Ramachandran; Illusions, January 2003.
- **Seeing in Black and White.** Alan Gilchrist; June/July 2006.

LOSING FOCUS

Spiking rates of nearsightedness are becoming a global health problem—but a simple behavioral change could be the solution

By Diana Kwon

For kids in Singapore, the pressure for academic success is intense. After the regular six- to eight-hour school day, many children attend extra classes at private schools and devote long hours to homework in the evening. In recent decades as study hours have expanded, so has the country's rate of nearsightedness—to epidemic proportions. An astonishing 80 to 90 percent of newly minted high school graduates in Singapore are myopic. The same is true in China, Taiwan, Japan and South Korea—all places where kids now spend far more time hunched over a desk or computer than did previous generations. Rates are rising in other developed nations as well. In the U.S., the prevalence of myopia nearly doubled from 25 percent in the 1970s to 42 percent in the early 2000s.

If present trends continue, fully half the world—more than four billion people—will need glasses by 2050, according to projections made by researchers at the Brien Holden Vision Institute, headquartered in Australia. This alarming forecast, published in *Ophthalmology* earlier this year, was based on an analysis of 145 studies of myopia rates around the globe. "That was the first really worrying statistic," says Kovin Naidoo, a vision researcher at the University of KwaZulu-Natal in South Africa who was involved in the study. "Any public health problem

ILLUSTRATION BY *Adam McCauley*

that affects 50 percent of the population is a bloody important issue."

Myopic individuals have an eyeball that is slightly too long. This deformity causes images to fall in front of the retina, rather than directly on it, making objects that are far away appear blurry. Myopia typically starts in childhood or adolescence and continues progressing into the 20s when the eyes are fully grown.

For most shortsighted people, clear vision can easily be restored with contact lenses, glasses or surgery. But in severe cases, which physicians classify as "high myopia," the eyes continue to stretch to dangerous levels, increasing the risk for retinal detachment, cataracts, glaucoma and other conditions that can lead to blindness. Unfortunately, the new study predicts that cases of high myopia will *also* rise—from 3 percent of the global population in 2000 to 10 percent by 2050, leaving an estimated 938 million people at risk of losing their eyesight.

For a long time, researchers attributed nearsightedness to genetics, but this could not explain why myopia rates were so quickly reaching epidemic levels. Once it became clear that environmental factors were to blame, the first, most obvious culprit was increased time spent on close work—reading, writing and staring at screens. More recent studies, however, are converging around a different idea: bright sunlight helps to regulate normal eye growth, and too much time indoors—whether studying, playing video games or something else—derails this process. This revelation has opened the door to a new way to prevent myopia that may be easier than bucking cultural trends emphasizing schoolwork: get kids outdoors.

Bespectacled Bookworms

All sight begins with light. The pupil expands and contracts to control how much light enters the eye. The clear cornea and lens bend the light, focusing it directly on the sensitive nerve cells of the retina. Here the rod and cone cells come into play, converting light into electrical impulses that travel to the brain. When all goes well, this journey enables us to view the world around us. But a flaw at any point in this process will introduce problems.

When the eyeball is too long, it focuses light in front of the retina, sending the brain a blurry image. We can compensate by squinting our eyes, which reshapes the lens and adjusts the path of light. But this is only a temporary fix. After months of straining eye muscles to see blackboards, kids—or their parents or teachers—will realize they have a vision problem and get fitted for their first pair of glasses.

In Asia, such trips to the optician have been on the upswing for half a century. Some of the first evidence that a myopia epidemic was under way came from studies of military conscripts in Singapore. Because two years of military service is mandatory for all young men and all recruits have their eyes tested, researchers could look at nearly the entire male population. Over the years the data revealed a dramatic rise in shortsightedness: 26 percent in the late 1970s, 43 percent in the 1980s and 83 percent by the late 1990s. "We think the huge generational effect [occurred] because about 50 years ago, the school system was different—it was not so intensive," says epidemiologist Seang-Mei Saw, head of the myopia unit at the Singapore Eye Research Institute. "If you just speak to the older and the younger generations about what they did when they went to school, you know that the lifestyle has changed tremendously."

If present trends continue, fully half the world—more than four billion people—will need glasses by 2050. And high myopia, a condition that can lead to blindness, will triple.

In many recently industrialized Asian countries, high-intensity education has become the norm amid fierce competition for limited spots in the nations' universities. In Shanghai, for example, 15-year-olds spend about 14 hours a week on homework compared with six hours in the U.S. Nearsightedness is common among the intellectual elite. True to the stereotype of the bespectacled bookworm, people with higher levels of education, test scores and IQ are all more likely to need glasses. "There is remarkably consistent evidence that people who have more years of education are more myopic," says Ian G. Morgan, a longtime myopia researcher at the Australian National University.

The connection therefore seemed crystal clear: more education meant more time doing close work, thereby causing irregular growth. But a more detailed look at myopia research presented a hazier picture. Evidence emerged that it was the lack of time outdoors, rather

FAST FACTS

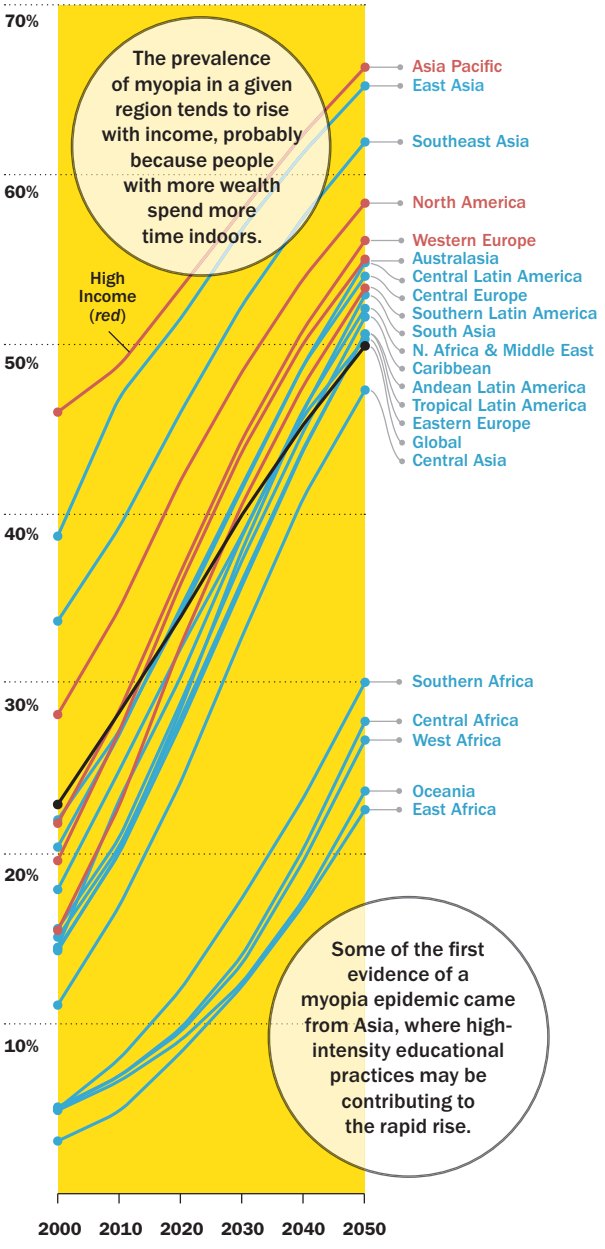
THE MYOPIA EPIDEMIC

1. By 2050 some researchers estimate that half the world's population will be nearsighted—an increase that suggests more and more people are at risk for serious vision problems.
2. Although researchers once attributed such shortsightedness to the eyestrain associated with "near work," such as reading or writing, newer evidence suggests light exposure is a critical factor in ensuring normal eye development.
3. Evidence in humans suggests that increasing children's time outdoors and in the sun can help stem the rising rates of myopia.

than time spent doing near work, that was behind the myopia boom. A 2007 study by researchers at Ohio State University was one of the first to support this conclusion. Using survey data from the parents of 514 grade-schoolers, it found that once time spent outdoors and parental myopia were taken into account, the effect of reading hours disappeared.

Around the same time, myopia researchers in Singapore and Australia, led by Kathryn Rose, then at the University of Sydney, conducted another questionnaire-based study comparing the prevalence of myopia in six- and seven-year-olds with Chinese ancestry in Sydney and Singapore. They found that although children in Sydney actually spent more time reading and doing near work, only 3 percent were myopic compared with 29 percent in Singapore. Australian children spent more time outdoors: more than 13 hours per week in Sydney compared with just three in Singapore. "Children in Australia actually did more near work because they read for pleasure, whereas the children in Singapore read only for school," says Morgan, who also took part in the study.

Soaring Rates of Nearsightedness



TIFFANY FARRANT-GONZALEZ (*illustration*); SOURCES: "GLOBAL PREVALENCE OF MYOPIA AND HIGH MYOPIA AND TEMPORAL TRENDS FROM 2000 THROUGH 2050," BY BRIEN A. HOLDEN ET AL.; IN *OPHTHALMOLOGY*, VOL. 123, NO. 5; MAY 2016 (*myopia prevalence*); GLOBAL BURDEN OF DISEASES, INJURIES, AND RISK FACTORS STUDY, INSTITUTE FOR HEALTH METRICS AND EVALUATION (*classifications by high-income region*)

Antimyopia Action

Clearly, being outdoors helps—but why? This question was hard to answer with human studies. To find the underlying mechanism, scientists needed to probe the chemistry inside the eye. To that end, researchers have induced myopia in animals such as chickens, tree shrews and monkeys. One way to do this is to prevent light from reaching the eyes by temporarily sewing them shut or covering them with frosted goggles. Without input from the outside world, the young animals' eyes overgrow and become severely nearsighted. A second and newer method is to place lenses over the eyes that focus images behind the retina. In consequence, eyes gradually compensate for the blurry image by becoming longer and myopic.

Much has been learned from these experiments, however disturbing they may sound. "I could tell from the chemistry of the retina in those monkeys which ones were myopic and which ones weren't," says Richard Stone, an ophthalmology researcher at the University of Pennsylvania. "And that was just astonishing."

These techniques revealed that when the retina detects blurry images, it releases chemical signals into the eye that control how large the eye will become and how quickly it will grow. "If you can convince the cells [in the retina] either by removing the blur or by chemical stimulation not to send the signals that cause the eye to elongate, then you can slow myopia," says Thomas Norton, a researcher studying myopia in animals at the University of Alabama at Birmingham.

Although scientists have yet to characterize all of the signals involved, one appears to be dopamine, a neurotransmitter that prevents eye growth. Light stimulates dopamine release, which suggests it could be mediating light's antimyopic effects. Indoors, light intensity is low—a typical office or classroom provides light levels around 100 to 500 lux. In comparison, a cloudy day can provide up to 15,000 lux, and a sunny summer day can offer up to 130,000 lux. "The current thinking is that the elevated outdoor light levels raise the amount of dopamine that is being produced and released in the retina and that this is counteracting the signals for the eye to get longer," Norton says.

A group of eye researchers at the University of Tübingen in Germany was the first to find convincing evidence for this idea. In 2009 they found that exposure to sunlight (30,000 lux)

THE AUTHOR

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and very bright artificial lights (15,000 lux) successfully prevented experimental myopia from developing in chickens. Then, in 2010, they discovered that injecting a drug (spiperone) that blocks dopamine activity into the eyes of myopic chicks could abolish the protective effect of light. Soon after, another group found the same protective effect of light in monkeys. But dopamine is unlikely to be the whole story. A 2011 study in guinea pigs found, for example, that drugs that increased dopamine activity did not consistently prevent myopia.

Some researchers think that the timing of light exposure is important. Like many other systems in our body, such as body temperature and hormone release, the length of our eyeballs has a daily cycle—they tend to be longest at midday. Dopamine levels in the eye also fluctuate through the day. They rise during daytime and fall at night. Melatonin has the opposite pattern, increasing at night, and it, too, has a role in eyeball development. The fact that these temporally tied activities affect the eye's growth hints that the body's cycle of circadian, or daily, rhythms may be related to eye health as well. Debora L. Nickla of the New England College of Optometry and others are investigating whether distorted circadian rhythms might play a role in the development of myopia.

Early studies in chickens found that eyes grow excessively under constant light or constant dark. But according to Nickla, these studies do not provide an accurate picture, because circadian rhythms were too severely altered. She is now investigating what happens when these rhythms are more subtly disturbed. One of her recent studies, published this year in *Experimental Eye Research*, revealed that two hours of light (700 lux) in the middle of the night was enough to alter eye growth. These preliminary studies point to the possibility that as children spend more late nights browsing the Web or crouched over their textbooks, altered circadian cycles may take a toll on their developing eyes.

Saving Sight

Although many questions remain about how light affects eye growth, faced with exploding rates of myopia, clinical researchers have begun testing myopia-prevention approaches involving light. Government agencies in Asian countries have started to push such interventions because of the overwhelming need.

In one study, which began in 2009, a group led by Pei-Chang Wu, an ophthalmology researcher at Kaohsiung Chang Gung Memorial Hospital, conducted a clinical trial in Taiwan with 571 elementary school students. Half of the children got an extra 80 minutes of outdoors recess each day for a year. The result: only 8 percent of those students developed myopia over the course of the study, whereas 17 percent of those in the other group needed glasses.

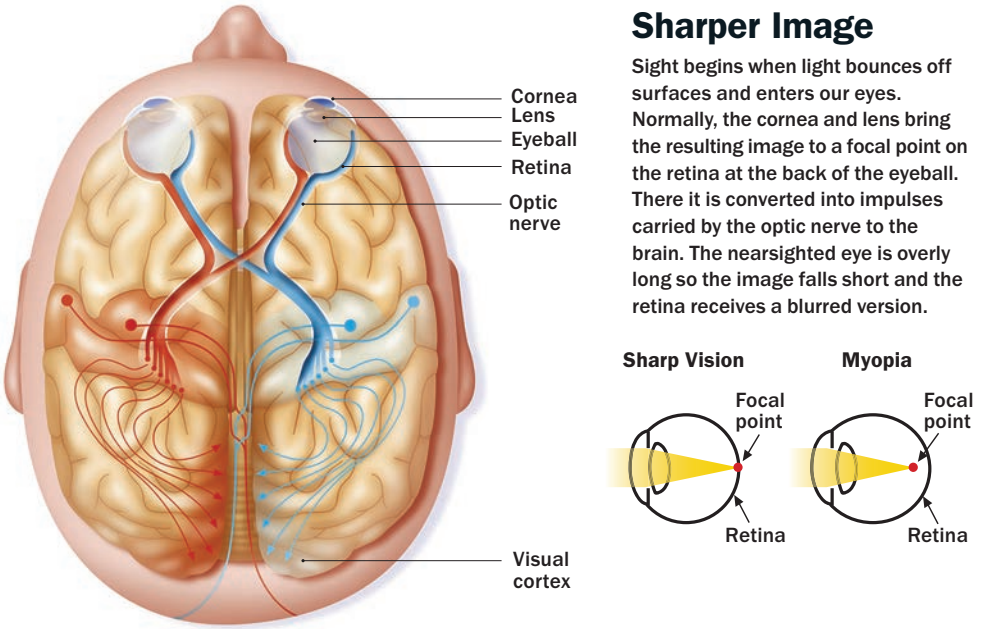
Around the same time, Morgan and his colleagues conducted a similar trial in Guangzhou, China. They found that children who received an extra 40 minutes of mandatory outdoor time every day for three years were 23 percent less likely to develop myopia than those who did not.

Sunlight can protect children from developing myopia, but whether it can slow down its progression in kids who already need glasses is unclear. "The results are mixed," Saw says. Some studies have found that outdoor time has a modest effect on progression. Others, such as Wu's study, found that being outdoors did not significantly alter outcomes for kids who were already myopic.

Yet simply delaying the age when children become myopic can have a major impact. Early onset increases the risk for high myopia because the eye has more time to stretch to pathological levels. Luckily, for those who have myopia, there are other treatment options that can help slow progression, including atropine eye drops and specially designed contact lenses [*see box on opposite page*]. "Myopia is a very difficult and persistent problem that is not going to go away easily," Norton says.

A Clear Future

In Asian countries with a culture stressing academic achievement, interventions that take time away from studying may not be the best option. "Even with the trial we did in Guangzhou," Morgan says, "by the end of the three-year period we were starting to get pushback from



Sharper Image

Sight begins when light bounces off surfaces and enters our eyes. Normally, the cornea and lens bring the resulting image to a focal point on the retina at the back of the eyeball. There it is converted into impulses carried by the optic nerve to the brain. The nearsighted eye is overly long so the image falls short and the retina receives a blurred version.

GETTY IMAGES (*brain*); *SCIENTIFIC AMERICAN MIND* (*diagrams*); SOURCE: ANDREI V. TKATCHENKO *Columbia University Medical Center* (*diagrams*)

Slowing Myopia Progression

Spending time in the sun can help prevent myopia or delay its onset, but it may not be helpful to children who are already nearsighted. Researchers are investigating a variety of interventions that have shown promise in slowing the aberrant eye growth that causes sight to worsen, which is crucial to preventing high myopia, a severe type that can lead to blindness.

Atropine Eye Drops	Orthokeratology (Ortho-K)	Multifocal Contact Lenses and Eyeglasses
Drops of atropine, a drug that blocks acetylcholine receptors in the eye, can stop or slow myopia's progress. Researchers have been investigating it since the 1990s. Initial studies found unwanted side effects—pupil dilation, eye muscle paralysis and blurry vision for close objects. Lower doses, however, have virtually no side effects and are even better at slowing progression than higher doses. Low-dose atropine is one of the most well-studied and promising treatment options. It is currently available in many Asian countries. In the U.S., the FDA has approved only the higher-dose option.	Ortho-K contact lenses temporarily flatten the cornea, the transparent layer at the front of the eyeball. Worn during sleep, they allow users to see clearly during the day. First used to correct blurry distance vision, randomized clinical trials have since demonstrated that they can also slow myopia progression. Ortho-K lenses are expensive—the initial fitting and the first pair of lenses can cost between $1,500 and $2,000. And some ophthalmologists worry that wearing lenses at night can increase the risk for eye infections.	Conventional corrective lenses—whether in glasses or contacts—have a single power, or focal length, which moves the image from behind the retina to directly on it. But these lenses cannot correct for the close objects at the periphery that appear fuzzy to a myopic eye. Studies have shown that this blurring effect can actually stimulate further eye growth (though at a much lesser rate than not wearing lenses at all). To prevent myopia from worsening, researchers have developed a new type of corrective lens with regions of varying focal lengths to deal with the differences at the fringes of vision. Recent human studies have confirmed their ability to reduce the progression of myopia.

parents saying, 'Look, you're wasting our children's time. If they weren't outside, they would be studying.'"

He and his colleagues are looking at alternative ways to get children the sunlight they need. One idea they are testing is a glass classroom, a greenhouselike structure where students can get up to 9,000 lux of sunlight. Such edifices are expensive to build, so they are also investigating another, more cost-effective option: bright study lamps that can shine up to 10,000 lux of light. Feasibility studies show that children are receptive to both techniques. The researchers hope to take these ideas into formal clinical trials within the next two years.

In Singapore, Saw and her colleagues are working to promote outdoor time. "Children wanted to be outdoors," Saw says. "But sometimes there were no opportunities." Using fitness trackers that measure time outside and guided weekend visits to the park, she believes, can help parents and teachers encourage kids to spend less time indoors.

Even in places where myopia rates are low, experts expect that prevalence will rise with increasing modernization. In Africa, for example, technology has advanced rapidly in recent years. "People have gone from no landline phones directly to mobile phones, and children are spending more time with computers," Naidoo says. "[We have] an opportunity to prevent the trends that have developed in the rest of the world."

Unfortunately, these regions currently have limited access to eye care. Proper prescriptions are crucial—leaving blurry vision uncorrected can actually worsen progression. To address this issue, Naidoo and his collaborators are working to implement programs to fit children in developing countries with glasses.

For now, the consensus is clear. Sunlight helps, especially for children who are not yet nearsighted. Taking youngsters outdoors, Morgan says, "is the cheapest and easiest option."

In a sense, the myopia epidemic is but one of many examples of how human progress has inadvertently separated us from healthful habits. Just as science has revealed that, like generations past, we, too, need to sleep seven hours, exercise regularly and eat a balanced diet, another simple way to improve our health may be to tear ourselves away from our desk lamps and electronic devices and spend some time outdoors soaking up the sun. M

MORE TO EXPLORE

- **Myopia.** Ian G. Morgan, Kyoko Ohno-Matsui and Seang-Mei Saw in *Lancet,* Vol. 379, pages 1739–1748; May 5, 2012.
- **Ocular Diurnal Rhythms and Eye Growth Regulation: Where We Are 50 Years after Lauber.** Debora L. Nickla in *Experimental Eye Research,* Vol. 114, pages 25–34; September 2013.
- **Global Prevalence of Myopia and High Myopia and Temporal Trends from 2000 through 2050.** Brien A. Holden et al. in *Ophthalmology,* Vol. 123, No. 5, pages 1036–1042; May 2016.
- American Academy of Ophthalmology on myopia: **www.aao.org/eye-health/diseases/myopia-nearsightedness**

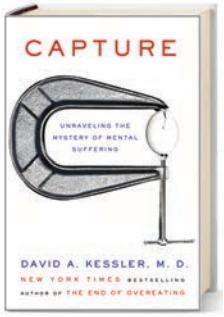
From Our Archives

- **Look into My Eyes.** Arryn Robbins and Michael C. Hout; January/February 2015.

HEAD CASE

Capture: Unraveling the Mystery of Mental Suffering

by David A. Kessler. Harper Wave, 2016 ($27.99; 416 pages)



When American novelist David Foster Wallace delivered the commencement address at Kenyon College in 2005, he urged the graduating class to "exercise some control over how and what you think." If you don't at least try to regulate your thoughts and behaviors, Wallace cautioned, you will go through life "dead, unconscious, a slave to your head." Wallace himself long suffered with unwanted negative thoughts and crippling self-doubt—and took his own life three years after that speech.

But can our mind become a "terrible master," as Wallace described? Kessler, the former commissioner of the U.S. Food and Drug Administration, has considered that question for the past two decades, studying how substances such as food, alcohol and tobacco can hijack our brain chemistry and compel us to act against our own best intentions—bingeing on brownies, booze or cigarettes.

He shared his basic theory of how this happens in his 2009 *New York Times* best seller, *The End of Overeating*. But in his latest offering, *Capture,* Kessler takes those ideas one step further: he asserts that the same biological mechanism that can derail our self-control is also largely to blame for our emotional suffering.

He calls this mechanism "capture" and describes it as the process by which some stimulus—a substance, place, thought, memory or person—can take hold of our attention and shift our perception. "Once our attention becomes increasingly focused on this stimulus," Kessler writes, "the way we think and feel, and often what we do may not be what we consciously want." In other words, when capture is set in motion, it can make us feel that we have no control over our thoughts or actions.

For the most part, the book serves up a theoretical take on the psychological forces that dictate our destructive impulses, such as self-doubt and anger, and seed our mental afflictions, such as depression and addiction. But Kessler also sketches out some neurobiological underpinnings for his theory. In the brain, he explains, "capture is the result of neural patterns that are created in response to various experiences." Over time our neural response to a stimulus can become automatic, and when that response does not match our conscious intentions, we feel blown off course.

Kessler illustrates his theory with a series of vignettes, exploring Wallace's lifelong struggles and Colorado cinema shooter James Holmes's obsessions, among others. Capture can poison the mind, Kessler notes, but it can also provide the antidote. He profiles some people who escaped distressing feedback loops and found stability by replacing an unhealthy mindset or preoccupation—say, overwhelming anxiety—with a more positive one, such as exercise.

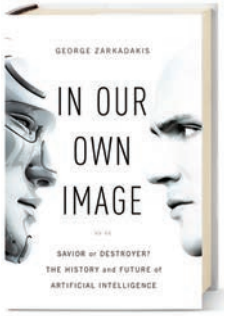
These stories about real people are engaging yet ultimately provide only anecdotal support for Kessler's theory. Some readers may be left craving more scientific evidence to better understand just how capture works, what triggers it and how we can break free.

—Lindsey Konkel

ARE HUMANS DOOMED?

In Our Own Image: Savior or Destroyer? The History and Future of Artificial Intelligence

by George Zarkadakis. Pegasus Books, 2016 ($27.95; 384 pages)



In the film *Avengers: Age of Ultron,* Tony Stark (aka Iron Man) and Bruce Banner (aka the Hulk) develop a powerful artificial intelligence to perfect Stark's global defense system. The AI, Ultron, immediately decides that the only good way to defend humans is by, well, *destroying* them. Skynet, the AI that wakes up in the *Terminator* movies, arrives at a similar conclusion, which perhaps gives new meaning to the old saying "Great minds think alike."

Is the human race really racing down the road to its own extinction through the engineering of AIs that are smarter than we are? In his new book, *In Our Own Image*, AI expert Zarkadakis explores this and related questions with remarkable ingenuity, clarity and breadth, weaving together a tapestry of material drawn from a range of disciplines—not only computer science but history, philosophy, psychology and neuroscience.

We have already created smart machines, but we are far from cracking the big nut, consciousness—and not, he adds, because this cannot be done but because we have been slow on the engineering side. Neuroscience is revealing that consciousness results from an integration of information flowing in complex loops from multiple parts of the brain to the neocortex. In theory, we can build circuits that work the same way, Zarkadakis says, and the "neuristors" and other so-called neuromorphic devices invented in recent years are gradually moving us in this direction.

He does a particularly good job answering one of the most basic questions about AI: Why are we trying so hard to create *artificial* minds when we have so many real ones right at hand? He argues that we are driven to do so by ancient, unconscious tendencies to imbue inanimate objects with humanlike spirits. We have created totems for thousands of years, and praying to them has given us a feeling of control over our lives; the ultimate expression of these tendencies would be the creation of an inorganic object that we can truly control, one that perfects human abilities.

The problem here is that a split second after we have created that entity, it will, like Ultron, almost certainly transform itself into a much more powerful entity over which we have no control. When that first AI wakes up into a state of humanlike consciousness, it will probably be concerned about its survival, and so its first act might just be to upload itself to the Internet. Zarkadakis notes that physicist Stephen Hawking and others have issued dire prognoses about what will happen next, but he suggests that what follows is "simply unpredictable"—and little more than a matter of faith at this point.

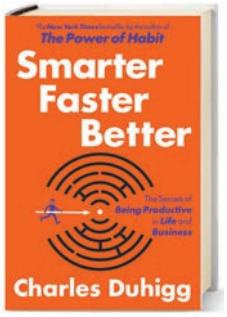
The bottom line is that inexorable, largely unexamined forces are driving us at lightning speed toward a pivotal moment for our species. Let's *examine* this process, Zarkadakis says, rather than mindlessly allow it to overtake us.

—Robert Epstein

PRACTICE MAKES PERFECT

Smarter, Faster, Better: The Secrets of Being Productive in Life and Business

by Charles Duhigg. Random House, 2016 ($28; 400 pages)



Executives, managers and psychology fans may not find many truly novel concepts in journalist Duhigg's new book about productivity. It sifts through much of the same theoretical territory around goal setting, team building and focus as many other psych and management texts. That said, no one has ever explained these ideas the way Duhigg does. He delves into the neuroscience behind superproductive people and illustrates key lessons through a stunningly diverse collection of real-life stories from Google engineers, airplane pilots, retirees, even creative mavericks, including *Saturday Night Live* creator Lorne Michaels and the team behind the animated blockbuster *Frozen.*

The subject matter makes the book a dense read at times, but Duhigg makes up for it with moments of brilliant storytelling. Take chapter three, which reads more like the script for an action-packed thriller than a popular science book. Quoting conversations caught on the in-flight recorder, Duhigg recounts the terrifying 2009 crash of Air France Flight 447, which plunged into the Atlantic Ocean off the coast of Brazil, killing everyone onboard. According to Duhigg, the captain fell victim to so-called cognitive tunneling, a "mental glitch that sometimes occurs when our brains are forced to transition abruptly from relaxed automation to panicked attention."

Trapped in a cognitive tunnel, people become preoccupied with immediate tasks and fail to see the bigger picture. So after cruising through most of the flight on literal autopilot, the captain and his copilot could not react effectively when the plane unexpectedly climbed too high and the engines started to stall. "As the … alarms blared, [the pilot] entered a cognitive tunnel. His attention had been relaxed for the past four hours," Duhigg explains. "Now, amid flashing lights and ringing bells, his attention searched for a focal point." Unfortunately for the 228 people onboard, he could not find one fast enough.

Duhigg's argument is not that this pilot was incompetent but that his brain had not been properly trained for such a moment of crisis. He contrasts this harrowing scene with another emergency, which occurred on Qantas Flight 32 a year later. You name it from the "in the event of" list on the in-flight safety card, and it happened: an oil fire, a shattered engine, a fuel leak. Panicked passengers actually watched the wing fall apart on the entertainment screens, thanks to a handy camera mounted on the plane's tail. And yet this pilot sidestepped cognitive tunneling to successfully crash-land at Singapore airport and save his passengers.

The difference? The Qantas captain was known for his habit of rehearsing what-if scenarios with his crew—a concept that psychologists refer to as mental modeling. Before each flight he would quiz his copilots about what screens they would look at first during a crisis or where their hands would go if an alarm sounded. "He had envisioned moments like this hundreds of times," Duhigg writes. "He had a picture in his mind of how to react." So as the nearly unimaginable unfolded, the pilot and crew had in fact already imagined how best to respond.

Such heroics may sound superhuman, but Duhigg makes the case that they are not. Anyone can learn how highly productive people operate and apply their secrets to situations in their own lives—from landing a crippled plane to calming a screaming toddler. One of the best ways to be "smarter, faster, better," as it turns out, is just what your parents told you when you were a kid: practice, even if that practice is only in your head.

—Sunny Sea Gold

ELIZABETH ALTER (*Duhigg*)

Q&A with Charles Duhigg: *Smarter, Faster, Better: The Secrets of Being Productive in Life and Business*

Scientific American Mind's "How to Be a Better …" columnist Sunny Sea Gold interviewed the best-selling author about what makes some people superhumanly productive. An edited transcript of their conversation follows.

Let's start at the beginning—for the reader, anyway. The title sounds a bit like a self-help book. Is it meant to be?
I don't think there's anything wrong with trying to help folks—but at the end of the day, I think self-help has a very flimsy sound to it, and this book is based on a ton of reporting. Talking to researchers and neuroscientists, reporting in the field. I hope people will read this book and learn how to become more productive. Because at the core of productivity is this insight that you don't have to work harder, but you have to work smarter by essentially understanding how your brain works. And so, yes, it does have some self-help to it, but I hope in the best way.

The book, in a nutshell, is about productivity. Tell me about the most productive time in your life.
Actually, through the process of writing this book, I got much more productive. It helped me understand that there were changes I could make in my life that would really improve my productivity. A great example of this is to-do lists. The way I used to write them is kind of the way everyone does: I would write a couple of easy things on the top and at the bottom some of the big things I was hoping to get done. Sometimes at the very top, I'd even write something I'd *already done* because it felt good to sit down and cross something off right away. Until I talked to psychologists about it. They said, "You're using your to-do list for mood repair, not getting things done! You need to take those big, important goals and put them at the *top* of the page, constantly remind yourself that there is something bigger and more important that you're chasing after, so you don't get distracted by the smaller things."

These are called stretch goals—put these at the top of the page and underneath put those you need a plan for. Say specifically what you want to get done and how you are going to measure it. What's your timeline? These are known as SMART goals. The acronym stands for specific, *m*easurable, *a*chievable, *r*elevant and *t*ime-bound. What really matters there is that I have a *plan* when I sit down at my desk in the morning. But also, just because I get through some subgoal, it doesn't let me *stop* [there]—it reminds me that I need to keep on going, that there's something bigger that I'm chasing after.

Your CV reads like an impossible list of high-level accomplishments. Yale, Harvard, *Los Angeles Times, New York Times,* Pulitzer, best-selling author. Have you ever been mediocre?
[Laughing] I'm mediocre all the time! The reason I'm laughing is that sometimes I will actually ask my wife, "If I'm so smart, why do I keep making all these stupid mistakes?" The truth is, I think all of us struggle all the time; doing good work always involves some struggle. One of the things very productive people do is they're much more comfortable with tension and willing to embrace it. Like in the chapter on *Frozen,* the creators were willing to say that there's a problem and that we don't have the answer yet—we're eventually going to find it, but it's going to be really hard until we do. Some people back away or shut down when it gets hard. Really productive people say, "This is hard, and that's okay. It means I'm on the right path."

I was fascinated by the stories about airplane emergencies and how an increase in automation can lead to cognitive hiccups. What do you think of things like self-driving cars? Are you antiautomation?
We know that as we are becoming increasingly automated, the odds of having these lapses in attention become more and more real because people become less aware of what's around them. That's why building mental models is so useful [in practicing for potential outcomes]. On the subway in the morning, for instance, I used to use the time to read the newspaper. Now what I do is I look at my calendar and close my eyes and try to envision my day a little bit. I think through, "What do I expect to happen in that meeting or this one? What might go awry?" Engaging in this seven-minute exercise sharpens my focus so that when things happen that might have caught me off guard, I'm prepared for the unexpected because I've thought it through.

You write that people who are good at "mental modeling" make more money and get better grades and that part of that process is narrating your life, coming up with theories and making guesses. In that case, my four-year-old is going to be valedictorian and a billionaire—constant outer monologue! Can we learn about being productive and successful from children?
Our four-year-old does the same thing! My wife and I love it—he just kind of starts *going.* One of the things we know about most productive people is they tend to be much more conscious about what's happening in their head. They assert more control over their cognitive processes. For kids, this is just natural. They tend to tell us what they're thinking about and how they're thinking about it because it's all so new. At the end of the day, [increasing productivity] is really about appreciating how your brain works and taking advantage of what we've learned from neuroscience.

Back to the title. Sometimes when I see a "self-improvement" message, my initial reaction is to rebel. Do you feel a sense of pressure around our culture's quest for betterment? Or is it our higher purpose as humans to strive?
One of the big things to take away from this is that most of us are doing great. Right? When we talk about productivity, we're not talking about jamming more work or hours into the day; we're talking about letting people achieve their goals with less stress and less waste and less struggle. For some, it might mean making reading and sending e-mails easier. For others, it may be getting more time with your kids. Part of the critical choices that people need to make to become more productive is to ask themselves, "What does productivity actually mean to me? What do I want to get out of the day, the week or my life?" You don't want to be running toward the wrong finish line.

ROUNDUP

Our Spiritual Path

Two books examine the science of enlightenment

"We are all mentally ill," a Buddhist monk once told James Kingsland, a science editor for the *Guardian* newspaper. Intrigued, Kingsland decided to probe Buddhist philosophy and discovered a view of the human mind as deeply flawed: until we reach enlightenment, we continue to suffer, always wanting, obsessing and worrying. In **Siddhartha's Brain: Unlocking the Ancient Science of Enlightenment** (William Morrow, 2016; 352 pages), Kingsland explains that the Buddhist line between mental health and illness is not so clearly defined as it is in the West; instead Buddhism sees our psychological well-being along an expansive spectrum. In his book, Kingsland delves into the history of Buddhism and teachings of Siddhartha (also known as Buddha) while weaving in recent scientific research on mindfulness meditation. He reveals not only how mindfulness meditation can rewire the human brain and help us achieve a sense of spiritual fulfillment but also how we can easily integrate the practice into our daily lives.

But how do we know when we are truly on the path to enlightenment? Or when we have reached our goal? In **How Enlightenment Changes Your Brain: The New Science of Transformation** (Avery, 2016; 288 pages), neuroscientist Andrew Newberg and author Mark Robert Waldman try to unlock the neural foundations of enlightenment—which they both claim to have reached. The duo takes us on their research and personal journeys to understand this abstract state. They scan the brains of deeply religious individuals—Buddhist meditators, Franciscan nuns, Sufis—as well as their own brains, hoping to determine what neural circuits give rise to enlightenment. They also map out neural changes associated with an enlightened state—observing, for instance, a dip in activity in the frontal lobe, which oversees our logical reasoning skills. They conclude that most people can attain some form of enlightenment through a variety of meditative and religious practices. The latter part of the book provides a rough guide. The authors tout many benefits—such as less stress and greater happiness—although some meta-analyses suggest the scientific evidence is thin. In chapter one, Newberg and Waldman confess that enlightenment is "almost impossible to relate in words." It seems even harder to pin down with science.

—Victoria Stern

Do statins produce neurological effects?

—**Alan Cleugh** U.K.

Beatrice Alexandra Golomb, a professor of medicine at the University of California, San Diego School of Medicine, responds:

Statins can indeed produce neurological effects. These drugs are typically prescribed to lower cholesterol and thereby reduce the risk of heart attack and stroke. Between 2003 and 2012 roughly one in four Americans aged 40 and older were taking a cholesterol-lowering medication, according to the Centers for Disease Control and Prevention. But studies show that statins can influence our sleep and behavior—and perhaps even change the course of neurodegenerative conditions, including dementia.

The most common adverse effects include muscle symptoms, fatigue and cognitive problems. A smaller proportion of patients report peripheral neuropathy—burning, numbness or tingling in their extremities—poor sleep, and greater irritability and aggression.

Interestingly, statins can produce very different outcomes in different patients, depending on an individual's medical history, the statin and the dose. Studies show, for instance, that statins generally reduce the risk of ischemic strokes—which arise when a blocked artery or blood clot cuts off oxygen to a brain region—but can also increase the risk of hemorrhagic strokes, or bleeding into the brain. Statins also appear to increase or decrease aggression.

In 2015 my colleagues and I observed that women taking statins, on average, showed increased aggression; men typically showed less, possibly because of reduced testosterone levels. Some men in our study did experience a marked increase in aggression, which was correlated with worsening sleep.

Statins may also affect neurodegenerative disorders, such as dementia, Parkinson's disease or amyotrophic lateral sclerosis (ALS). For instance, some patients taking statins develop ALS or ALS-like conditions with progressive muscle wasting, which sometimes resolve when the patients stop taking the medication. The drugs may play a role in triggering symptoms, at least in those cases, but may also prevent the progression of such conditions in some settings. One possible explanation is that statins cause increases or decreases in tissue damage known as oxidative stress, involved in neurodegenerative diseases.

The effects of statins are complex. We hope that further study will shed light on the neurological problems statins can cause and explain how to better protect those who experience these troubling complications.

What is loss aversion?

—**Claus Schittenhelm** via e-mail

Russell A. Poldrack, a professor of psychology at Stanford University, replies:

Imagine this scenario: a friend offers to flip a coin and give you $20 if it lands on heads. If it lands on tails, you give her $20. Would you take that gamble? For most of us, the amount you could possibly win would need to be at least twice as large as the amount you could lose before you would accept the risk. This tendency reflects loss aversion, or the idea that losses generally have a much larger psychological impact than gains of the same size.

So what causes us to be more sensitive to losses? In 1979 psychologists Amos Tversky and Daniel Kahneman developed a successful behavioral model, called prospect theory, using the principles of loss aversion, to explain how people assess uncertainty. More recently, psychologists and neuroscientists have uncovered how loss aversion may work on a neural level. In 2007 my colleagues and I found that the brain regions that process value and reward may be silenced more when we evaluate a potential loss than they are activated when we assess a similar-sized gain.

In the study, we monitored brain activity while participants decided whether to take a gamble with actual money. We found enhanced activity in the participants' reward circuitry as the amount of the reward increased and decreasing activity in the same circuitry as the potential losses accrued. Perhaps most interesting, the reactions in our subjects' brains were stronger in response to possible losses than to gains—a phenomenon we dubbed neural loss aversion. We also found that individuals displayed varying degrees of sensitivity to loss aversion, and these wide-ranging neural responses predict-

JAMIE CARROLL ©iStock.com

Why does time seem to speed up with age?

—**Esther Robison** New York City

James M. Broadway, a postdoctoral researcher in the department of psychological and brain sciences at the University of California, Santa Barbara, and **Brittiney Sandoval,** a recent graduate of the same institution, answer:

"Where did the time go?" middle-aged and older adults often remark. Many of us feel that time passes more quickly as we age, a perception that can lead to regrets. According to psychologist and BBC columnist Claudia Hammond, "the sensation that time speeds up as you get older is one of the biggest mysteries of the experience of time." Fortunately, our attempts to unravel this mystery have yielded some intriguing findings.

In 2005, for instance, psychologists Marc Wittmann and Sandra Lenhoff, both then at Ludwig Maximilian University of Munich, surveyed 499 participants, ranging in age from 14 to 94 years, about the pace at which they felt time moving—from "very slowly" to "very fast." For shorter durations—a week, a month, even a year—the subjects' perception of time did not appear to increase with age. Most participants felt that the clock ticked by quickly. But for longer durations, such as a decade, a pattern emerged: older people tended to perceive time as moving faster. When asked to reflect on their lives, the participants older than 40 felt that time elapsed slowly in their childhood but then accelerated steadily through their teenage years into early adulthood.

There are good reasons why older people may feel that way. When it comes to how we perceive time, humans can estimate the length of an event from two very different perspectives: a prospective vantage, while an event is still occurring, or a retrospective one, after it has ended. In addition, our experience of time varies with whatever we are doing and how we feel about it. In fact, time does fly when we are having fun. Engaging in a novel exploit makes time appear to pass more quickly in the moment. But if we remember that activity later on, it will seem to have lasted longer than more mundane experiences.

The reason? Our brain encodes new experiences, but not familiar ones, into memory, and our retrospective judgment of time is based on how many new memories we create over a certain period. In other words, the more new memories we build on a weekend getaway, the longer that trip will seem in hindsight.

This phenomenon, which Hammond has dubbed the holiday paradox, seems to present one of the best clues as to why, in retrospect, time seems to pass more quickly the older we get. From childhood to early adulthood, we have many fresh experiences and learn countless new skills. As adults, though, our lives become more routine, and we experience fewer unfamiliar moments.

> "The more new memories we build on a weekend getaway, the longer that trip will seem in hindsight. This so-called holiday paradox helps to explain our perceptions of time passing."

As a result, our early years tend to be relatively overrepresented in our autobiographical memory and, on reflection, seem to have lasted longer. Of course, this means we can also slow time down later in life. We can alter our perceptions by keeping our brain active, continually learning skills and ideas, and exploring new places. M

ed differences in their behavior. For instance, people with stronger neural sensitivity to both losses and gains were more risk-averse.

Another theory is that losses may trigger greater activity in brain regions that process emotions, such as the insula and amygdala. Neuroscientists Benedetto De Martino, Ralph Adolphs and Colin Camerer studied two individuals with a rare lesion on their amygdala and found that neither exhibited loss aversion, suggesting that the amygdala plays a key role. A larger 2013 study from Italian neuroscientist Nicola Canessa and his colleagues replicated our initial findings and also discovered that activity in the insula increased as the potential loss mounted. These findings, taken together, most likely help to explain loss aversion, but understanding exactly how these various neural processes play out in different individuals and situations requires further investigation.

Do you have a question about the brain you would like an expert to answer?

Send it to MindEditors@sciam.com

1 LETTER LINKS

Make your way from MINE to GOLD in four steps. At each one, change a single letter to form a common English word.

MINE

_ _ _ _

_ _ _ _

_ _ _ _

GOLD

2 SUBDIVISIONS

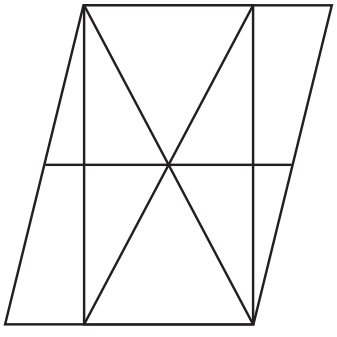
What amount is one third of one fourth of one tenth of $6,000?

3 POINTS OF COLOR

Pink is worth 25 points, blue is worth 30 and green is worth 35. Using the same scoring system, how many points is red worth?

4 TRIANGLE TALLY

How many triangles are contained in this image?



5 SHAPING UP

Each of the four shapes in this grid represents a number. The sums of each row and column are shown except for one. Find the missing sum.

O	Ø	X	▲	10
X	Ø	Ø	X	10
X	Ø	O	X	9
▲	▲	O	Ø	11
11	10	7	?	

6 MATCHING ANAGRAMS

Fill in the blanks by finding the words that fit the definitions on the left and, when anagrammed, also fit the definitions on the right.

Part of the neck _____ _____ **Piece of the window**

Basement _____ _____ **Visitor**

Be thrifty _____ _____ **A container**

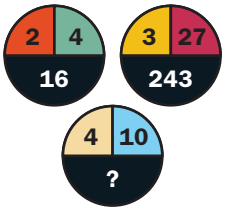
7 HIDDEN TRUTH

A truism is coiled in this grid. To spell it out, start with one letter and move to an adjacent letter in any direction. (Hint: Start with an "M.")

T	B	E	O	S	N	G	E	L	C	E
O	N	T	M	T	I	H	T	S	A	L
M	Y	H	E	I	E	R	Y	E	P	D
Y	A	O	P	M	V	E	T	I	O	N
E	N	R	T	T	I	N	U	S	E	C
M	O	A	N	T	H	G	B	I	N	S

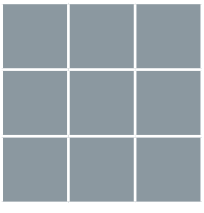
8 CIRCULAR LOGIC

Following the logic of the first two circles, find the number missing in the third.



9 MINI MAGIC SQUARE

Arrange the numbers 1 through 9 in the grid so that all the lines, columns and main diagonals add up to 15.



Answers

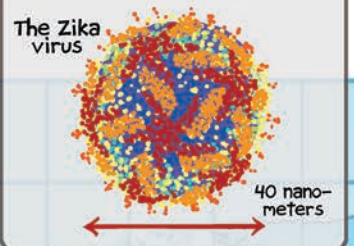
1. One solution: MINE, MIND, MILD, MOLD, GOLD.
2. $50. (6,000 ÷ 10 = 600; 600 ÷ 4 = 150; 150 ÷ 3 = 50.)
3. 20 points. (5 points for each consonant and 10 points for each vowel.)
4. 20.
5. 12. (O =1, Ø = 2, X = 3, ▲ = 4.)
6. NAPE, PANE; CELLAR, CALLER; SAVE, VASE.
7. Money may not be the most important thing, but everything else is in second place.
8. 160. (Square the upper-left number and multiply the result by the upper-right number.)
9. One solution:

6	7	2
1	5	9
8	3	4

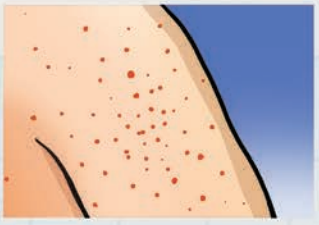
THE ZIKA VIRUS

BY DWAYNE GODWIN & JORGE CHAM

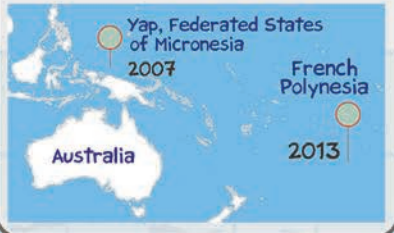
THE ZIKA VIRUS WAS FIRST DETECTED IN MONKEYS IN THE ZIKA FOREST OF UGANDA IN 1947.



IT WAS INITIALLY CONSIDERED BENIGN. INFECTION IN HUMANS WAS RARE AND ONLY APPEARED TO CAUSE A MILD RASH AND FEVER.

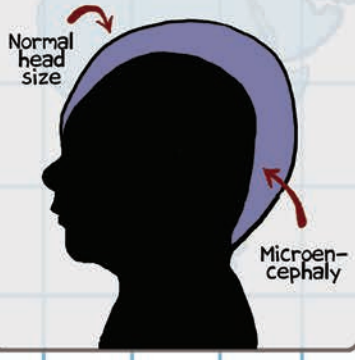


DURING OUTBREAKS IN 2007 AND 2013 IN THE PACIFIC, HEALTH OFFICIALS BEGAN TO SEE A LINK TO CERTAIN NEUROLOGICAL CONDITIONS IN HUMAN PATIENTS.

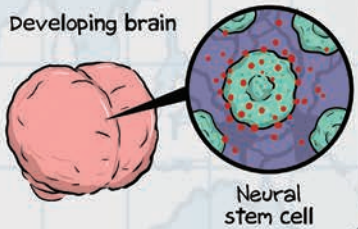


BY 2015 THE DISEASE HAD SPREAD THROUGHOUT ASIA AND SOUTH AMERICA AND IS NOW LINKED TO CASES OF INFANT MICROENCEPHALY.

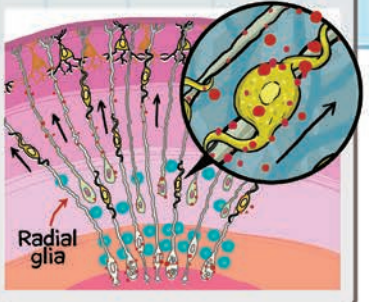
CHILDREN BORN WITH MICROENCEPHALY HAVE A MUCH SMALLER BRAIN AND HEAD. THEY MAY EXPERIENCE SEVERE INTELLECTUAL DISABILITY, SEIZURES AND EVEN DEATH.



SCIENTISTS BELIEVE THE VIRUS TARGETS A PARTICULAR PROTEIN CALLED AXL, WHICH IS PREVALENT ON THE SURFACE OF NEURAL STEM CELLS.



THE VIRUS KILLS THESE CELLS, AS WELL AS RADIAL GLIAL CELLS, WHICH HELP DEVELOPING NEURONS MIGRATE TO THE OUTER LAYERS OF THE BRAIN.



ZIKA INFECTS 1 IN 5 PEOPLE EXPOSED TO THE VIRUS AND CAN BE TRANSMITTED BY MOSQUITOES, BLOOD TRANSFUSIONS, SEXUAL CONTACT OR FROM MOTHERS TO THEIR FETUSES.

HEALTH OFFICIALS ARE URGING RESIDENTS AND TRAVELERS IN ZIKA-PRONE AREAS TO TAKE SPECIAL PRECAUTIONS.

BECAUSE THE BEST WAY TO STOP THE SPREAD OF A VIRUS ...

... IS FOR OUR KNOWLEDGE OF IT TO SPREAD EVEN FASTER.

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