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Why it may be
the best fix for
depression

THE CHEMISTRY
OF DESIRE

HOW TO LEARN A
NEW LANGUAGE

eBooks

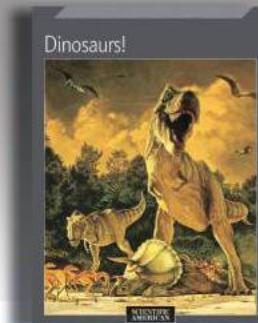
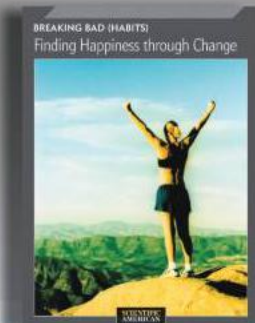
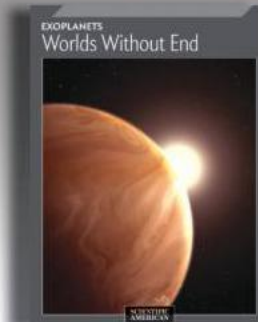
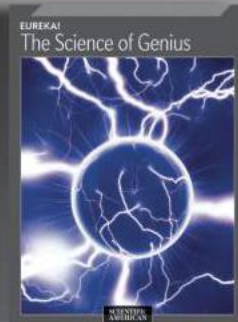
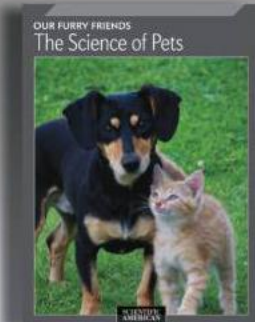
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FAVORITE**



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We all know that exercise is a good thing—for body and for mind. Decades of data have established it as one of the best ways to lower the risk of heart disease and stave off other ailments of aging, including dementia. But even after many years of covering health as a reporter and editor, I was genuinely surprised to learn about the depth of the evidence showing how powerful exercise can be in battling major depression. In our cover story, “Head Strong,” contributing editor Ferris Jabr reveals how moderate to vigorous exercise can be as effective as medication and therapy for many people with mild to moderate depression—and it certainly has the most salutary side effects of any treatment.

“Scores of experiments now show that exercise is much more than a temporary distraction from mental woes,” Jabr writes. His story, which begins on page 26, examines the research and explores the likely biological pathways through which working out works mental magic. These include strengthening our biochemical resistance to stress and promoting the growth of new brain cells.

Brain biochemistry looms large in another story in this issue. “The Currency of Desire,” written by journalist Maia Szalavitz and beginning on page 48, smashes some myths about everyone’s favorite neurotransmitter. Dopamine, long reputed to be the brain chemical that signals pleasure, turns out to have more to do with wanting than with liking. “This little molecule,” Szalavitz writes, “may unlock the intricate mystery of what drives us,” which helps to explain its role in everything from initiating action to addiction.

How to help children achieve their potential is a challenge that all principled societies must face. Two stories take a look at this from very different angles. In “The Stamp of Poverty,” beginning on page 54, neuroscientist John D. E. Gabrieli of M.I.T. and psychologist Silvia A. Bunge of the University of California, Berkeley, describe recently discovered differences in brain anatomy and function between kids growing up in poverty and more affluent children—findings that add urgency to the issue of extreme income inequality. In “Nurturing Genius” (page 40), journalist Tom Clynes reports on the lessons of a 45-year study of how best to educate our most intellectually gifted youth.

Finally, for a glimpse of a wildly different kind of intelligence, turn to page 62 and soak up “The Mind of an Octopus,” our excerpt from a new book by Peter Godfrey-Smith. You’ll likely agree with the author that the octopus possesses the closest thing on earth to an alien intelligence.

Claudia Wallis
Managing Editor
MindEditors@sciam.com

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For many people with depression, exercise may be the most effective, least expensive and safest treatment.

BY FERRIS JABR



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Overlooked in previous models of personality, moral character turns out to be key in predicting job performance and leadership potential.

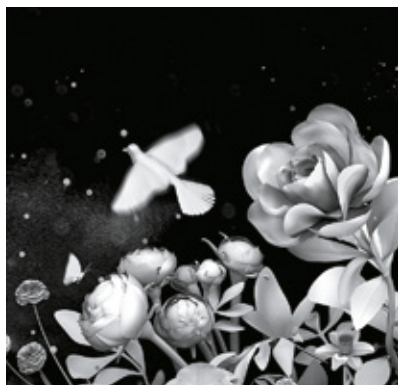
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A decades-long study of exceptionally gifted children reveals what it takes to hone the world's sharpest minds.

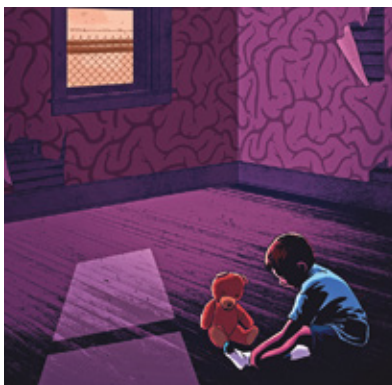
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Rethinking the “pleasure molecule” could help scientists better understand addiction, Parkinson’s disease and motivation.

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Growing up in a poor family can leave a mark on the developing brain. Understanding how and why has important implications for society.

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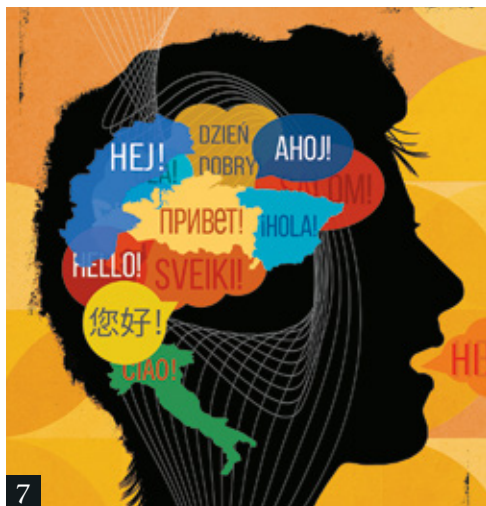


62 The Mind of an Octopus

Eight smart limbs plus a big brain add up to a weird and wondrous kind of intelligence.

BY PETER GODFREY-SMITH

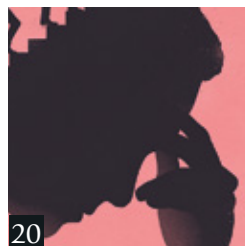
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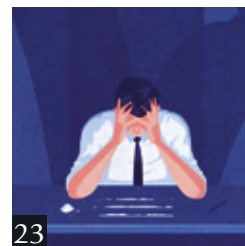
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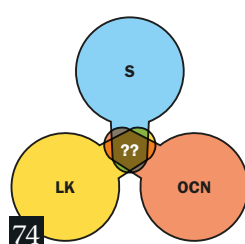
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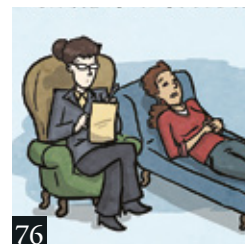
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A HAVEN AT HOME

Rachel Nuwer writes in “No Workplace Like Home” that people might work more productively in such a setting, but I would like to point out an additional benefit: if you experience environmental stressors such as sensitivity to fluorescent lighting, high-contrast patterns and background noises, you can control your environment at home and maximize concentration and focus and minimize visual and auditory sensory stress. And you can take breaks as needed and work according to your own time frame and circadian rhythm. Working remotely can also enable you to spend more time with family and engage in activities to unwind and de-stress, such as cooking healthy meals. If a person is diagnosed with a psychological or physical disability, working from home instead of an office may be an acceptable, reasonable accommodation to enable him or her to work at the job he or she is qualified to perform.

Thank you for bringing this option and its benefits to the attention of the public.

Shoshana Shamberg
 Baltimore

TAKE A BREAK TO MEDITATE

I read with interest the article “Give Me a Break,” by Ferris Jabr. I am a clinical psychologist with 30 years of experience

running a busy practice. I schedule two 20-minute meditation sessions every day, and as a result, I function better as a doctor and as a human being.

I have learned that researchers have proposed three major categories of meditation techniques, classified according to electroencephalographic measurements and the type of cognitive processing, or mental activity, involved: focused attention, open monitoring and automatic self-transcending.

Each technique has value, and I use all three in my clinical practice. I often recommend transcendental meditation to my patients, and I see good results in those who meditate regularly.

Mark S. Ellinger
 Delray Beach, Fla.

PARENTS SLEEP HALF-AWAKE

I was surprised that in his Consciousness Redux column “To Sleep with Half a Brain,” Christof Koch didn’t mention the light, fitful sleep anecdotally reported by some parents, especially moms, with newborns. As a veterinarian, I often use this phenomenon as an analogy when describing a similar response I have observed in dogs that are protective of their owners. Although I suspect most moms with young children eventually reach a point when they don’t sleep half-awake every night, there are still times, for example, when the kids are sick, when this mechanism kicks in again. I imagine grandparents may also go into this alert sleep mode when babysitting their grandchildren and get more restful sleep as soon as the parents return.

Myrna Milani
 Animal behavior consultant,
 TippingPoint
 Charlestown, N.H.

THE SPOTLESS MIND

Regarding “Trying to Forget May Cause Amnesia,” by Dinsa Sachan [Head Lines], I would add a different, but perhaps lesser, dimension to amnesia. Having grown up during the Japanese occupation of the Dutch East Indies in the Second World War, in which people of

THE SOCIAL MEDIA GENERATION

“Generation Z: Online and at Risk?” an excerpt from Nicholas Kardaras’s book *Glow Kids*, expounds on the perils of social media for today’s teens—from having fewer “real” friends to developing a technology addiction. A number of high school students wrote in via e-mail to express their opinions about the story’s claims. We have grouped some of their comments by topic.

—The Editors

How Many “Friends” Do You Really Have?

Brooke Harris writes that “most people now have over 300 friends on Facebook but don’t even talk to half of them.”

■ Kyle Anderson agrees: “On social media, I have a real conversation with only a few of my friends on Facebook every day; I talk to others but not very often.” ■ Dalton Hermes adds, “Friends on social media, to teenagers, do not mean much. We really only are true friends with a small group of people.” ■ Jake Mennen, on the other hand, notes that “having multiple friends on Facebook helps me connect with people I never thought I would be able to.”

Social Media Addiction

George Jeff writes, “I do not use social media myself, but I have seen some of my friends and family become addicted to it and use it constantly, to the point where they barely make any social contact outside of it, as they use it more and more.”

■ Katelyn Byerley adds, “As a teenager,



I understand how social media and texting are an addiction. People have withdrawal when they don’t have this luxury.”

Pulling the Plug on Phone Use

Sharon Heather writes, “I agree with the idea that parents should encourage their kids to not be on their phones all the time” but notes that “for that to work, parents need to get off their phones as well.”

■ Robert H. Youngren asserts that instead of limiting their children’s social media use, “parents should say little and instead encourage doing sports, going out with friends, or pursuing any hobby the kid likes.”

Does Social Media Magnify Peer Pressure?

Tessa Burger disagrees: “If somebody is going to be influenced, they are going to be influenced no matter what. I think what we should focus on more is teaching teens to resist peer pressure rather than blaming social media.”

European descent were put in internment camps, my suppression of bad memories has become a constant exercise. I even shut out some of what I hear. Couple that with dysfunction in my immediate family, and suppressing things has become a habit in my daily life. It becomes a “zone” I am in without realizing it, and even learning is done from this in-between state. This realization has come to me recently, but I made the connection, in particular, after reading this article. Thank you.

Joy von Ende-Reddy
Toronto

EXERCISE AND COGNITION

The answer to “How Does Exercise Benefit Cognition?” by David R. Jacobs and Na Zhu [Ask the Brains], was interest-

ing. But the authors did not discuss the reverse possibility: Might it be the case that people with better cognitive capabilities are also the ones who are better able to control and stimulate their physical capabilities? In other words, are they simply more disciplined and more motivated to achieve goals? Cause and effect might be reversed.

Antoon Kuijpers
Vlaardingen, the Netherlands

TEASING APART THE EFFECTS OF SPANKING

Reducing complex social and behavioral contexts to a single variable tends to lead to erroneous results. Although “What Science Really Says about Spanking,” by Melinda Wenner Moyer [Head Lines], indicates that researchers made an effort

to select out the effects of more violent methods of child control or abuse, it neglects to raise the context that situates such a complex phenomenon. Namely, who spansks? If that question were to be examined, taking into account cultural and familial context, it would give us a much truer picture of the sources of “negative outcomes” from spanking. Then there is that even more enticing question: Who doesn’t spank? Who are they? And what disciplinary methods fare best in terms of outcomes on children’s mental health and well-being?

Philip E. Wolfson
San Anselmo, Calif.

PSYCHOPATHIC PRESIDENTS

Kevin Dutton’s story “Would You Vote for a Psychopath?” ranks U.S. presidents based on assessments of psychopathic traits. All presidents are listed except Barack Obama. Why? Is it because he is a sitting president? If so, then why are the 2016 candidates who ran for president ranked? And more curiously, why are obvious psychopaths such as Joseph Stalin and Mao Zedong not included?

Harold R. Barbera
Tamarac, Fla.

THE EDITORS REPLY: Dutton created the table of past presidents based on a 2012 study co-authored by psychologist and Scientific American Mind advisory board member Scott O. Lilienfeld, who explains, “Obama was left out because the data were collected several years before he became president.” Dutton researched psychopathy among historical world leaders, and he notes, “This is an ongoing study, and the biographers for Stalin and Mao haven’t gotten back to me yet.”

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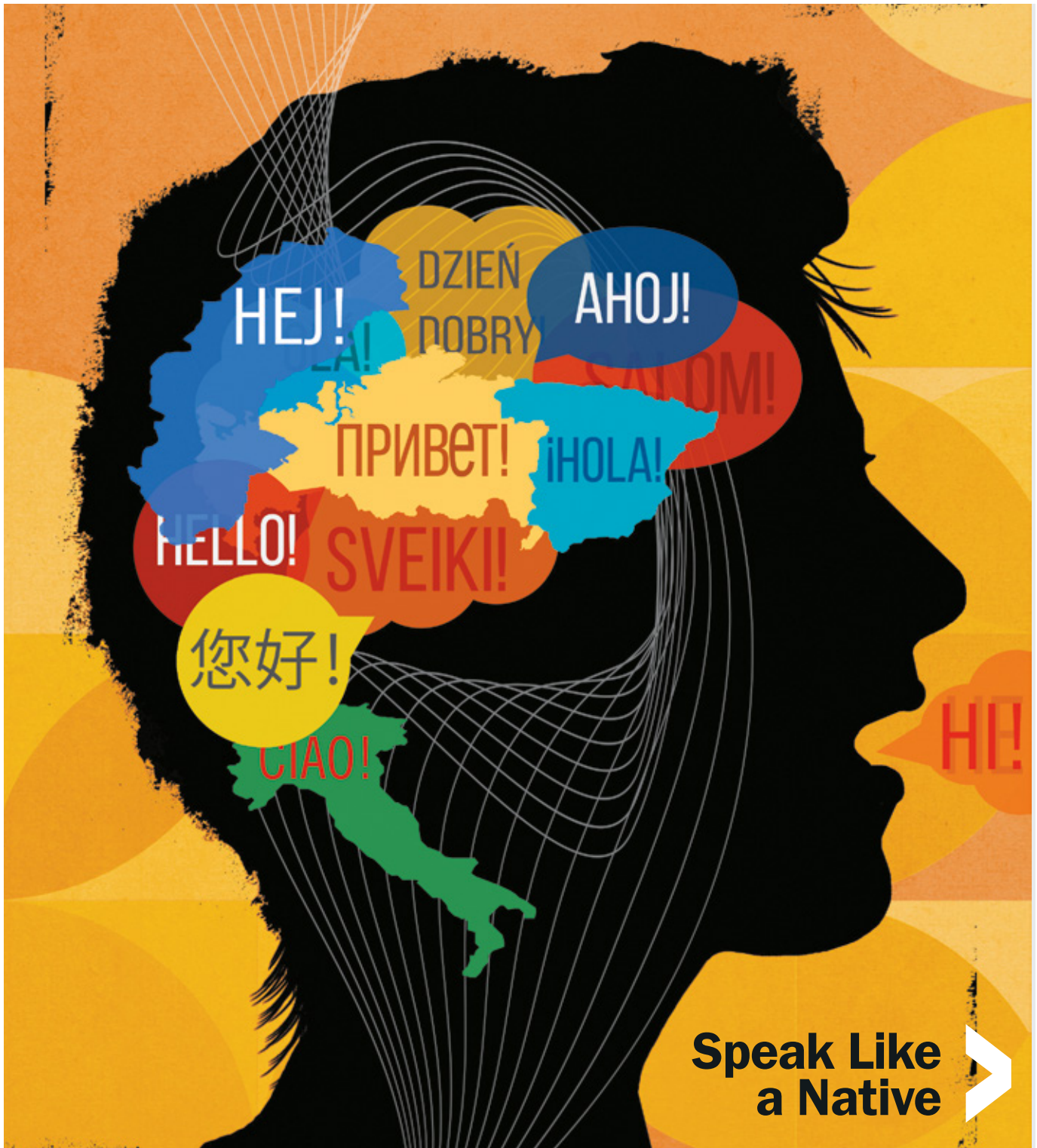
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Head Lines

A USER'S GUIDE TO THE BRAIN



So You Want to Learn Another Language

Whether you are going on a business trip to Shanghai or just want to impress your date with *la langue de l'amour*, there are many reasons to learn a foreign tongue. A wealth of research has looked at what helps. Other studies explore how individual brain anatomy and function could explain why some of us learn more easily than others.

Put on Telenovelas as You Cook

Hearing a foreign language in the background can help you learn it faster, even if you are not paying attention

Baffling grammar, strange vowels, quirky idioms and so many new words—all of this makes learning a new language hard work. Luckily, researchers have discovered a number of helpful tricks, ranging from exposing your ears to a variety of native speakers to going to sleep soon after a practice session. A pair of recent papers suggests that even when you are not actively studying, what you hear can affect your learning and that sometimes listening without speaking works best.

In one study, published in 2015 in the *Journal of the Acoustical Society of America*, linguists found that people who took breaks from learning new sounds performed just as well as those who took no breaks, as long as the sounds continued to play in the background. The researchers trained two groups of people to distinguish among trios of similar sounds—for instance, Hindi has “p,” “b” and a third sound English speakers mistake for “b.” One group practiced telling these apart one hour a day for two days. Another group alternated between 10 minutes of the task and 10 minutes of a “distractor” task that involved match-

ILLUSTRATIONS BY STEPHANIE DALTON COWAN



ing symbols on a worksheet while the sounds continued to play in the background. Remarkably, the group that switched between tasks improved just as much as the one that focused on the distinguishing task the entire time. “There’s something about our brains that makes it possible to take advantage of the things you’ve already paid attention to and to keep paying attention to them,” even when you are focused on something else, suggests Melissa Baese-Berk, a linguist at the University of Oregon and a co-author of the study.

In a 2016 study published in the *Journal of Memory and Language*, Baese-Berk and another colleague found that it is better to listen to new sounds silently rather than practice saying them yourself at the same time. Spanish speakers learning to distinguish among sounds in the Basque language performed more poorly when they were asked to repeat one of the sounds during training. The findings square with what many teachers have intuited—that a combination of focused practice and passive exposure to a language is the best approach. “You need to come to class and pay attention,” Baese-Berk says, “but when you go home, turn on the TV or turn on the radio in that language while you’re cooking dinner, and even if you’re not paying total attention to it, it’s going to help you.” —Veronique Greenwood

More than half of Europeans are bilingual or multilingual, as opposed to an estimated one quarter of Americans.

A Head for Foreign Tongues

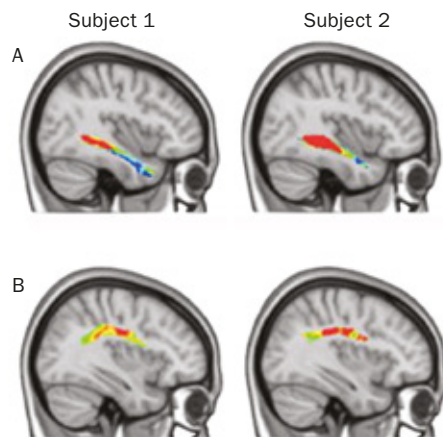
Brain scans may offer clues to a person's natural aptitude—and help those less gifted learn how to study better

Babies' ability to soak up language makes them the envy of adult learners everywhere. Still, some grown-ups can acquire new tongues with surprising ease. Now some studies suggest it is possible to predict a person's language-learning abilities from his or her brain structure or activity—results that may eventually be used to help even the most linguistically challenged succeed.

In one study, published in 2015 in the *Journal of Neurolinguistics*, a team of researchers looked at the structure of neuron fibers in white matter in 22 beginning Mandarin students. Those who had more spatially aligned fibers in their right hemisphere had higher test scores after four weeks of classes, the scientists found.

Wired for Learning

Your ability to learn a new language may be influenced by brain wiring. Diffusion tensor imaging of native English speakers learning Mandarin reveals that people who learn better have more aligned nerve fibers (shown with warmer colors) in two regions in the right hemisphere (A and B). In this case, subject 2, who has more aligned fibers, was a more successful learner than subject 1.



Like a freeway express lane, highly aligned fibers are thought to speed the transfer of information within the brain. Although language is traditionally associated with the left hemisphere, the right, which seems to be involved in pitch perception, may play a role in distinguishing the tones of Mandarin, speculates study author Zhenghan Qi of the Massachusetts Institute of Technology.

In another study, published in June 2016 in *Brain and Language*, EEG scans before an intensive online French course revealed patterns of brain-wave activity in a relaxed, resting state that correlated with completing the course quickly and easily.

In the past researchers have observed this kind of activity when people put together sentences, says Chantel Prat, the University of Washington psychologist who led the study. In this instance, it may be a reflection of the 16 subjects' ability to focus or follow instructions or another feature that aids in language learning, she notes. Prat is interested in studying whether neurofeedback—showing people their EEG images in real time to train them in certain types of brain activity—can prepare them to learn a language better. “The last thing I want someone to think is, ‘Oh, my brain is like this ... what’s the point? I can’t learn,’” Prat says.

What language aptitude really is and how it manifests in the brain are complex questions, touching on the nature of attention and even consciousness. “I think language is the most miraculous feat of the human brain,” Prat says. “When you try and learn a second language, you realize how challenging it is.” —V.G.



Tips for Picking Up a New Lingo

Although learning a language is harder as an adult than as a child, here are a few strategies that can help pave the way:

Watch social cues: Pay attention to nonverbal cues, such as eye gaze, gestures or pointing. They can enhance your understanding of sounds, words, phrases and even grammar.

Sleep on it: Going to bed soon after drilling vocabulary or other practice can help consolidate what you have learned.

Listen to your own accent: You can improve your pronunciation by recording yourself in conversation (as opposed to reading from a script) and practicing with a native speaker.

Tune out to tune in: Listening to language spoken in the background while doing another task can help you learn to distinguish among similar sounds.

Say it again: Hearing and repeating words and phrases can help you learn them faster and recall them better.

Immerse yourself: Of course, nothing is more effective for learning than complete immersion in the culture. Living and working with native speakers can round out this experience.

—Victoria Stern



(PHARMA WATCH)

A One-Dose Psychedelic Fix for Addiction?

A drug that mimics ibogaine, a hallucinogen used underground for decades as an antiaddiction agent, is now being tested in clinical trials

The psychedelic drug ibogaine is known for two things: its reputation in some circles as a panacea for addiction and the visceral hallucinations it induces. Positive anecdotes abound from people who have sought out the illegal drug at underground clinics. Just one dose, they say, brings near-instant relief from cravings and withdrawal symptoms, a veritable miracle for seemingly intractable addictions. But the side effects of this plant-derived substance can be dangerous or even deadly. Now, with encouraging evidence from animal studies, drugs are being developed to replicate ibogaine's impact on addiction without the side effects. A drug that is chemically related to ibogaine but lacks its hallucinogenic properties is set to begin phase II clinical trials in California early this year. If the results continue to be promising, addiction treatment as we know it could change radically.

For decades research on ibogaine has been stymied by its classification as a Schedule I drug, the most tightly regulated category. Yet the results of animal studies have been intriguing. In May 2016 a meta-analysis examining 32 such studies, mostly in mice and rats, found that ibogaine reduced self-administration of cocaine, opioids and alcohol. An earlier study from 2015 found that noribogaine, the substance that ibogaine breaks down to when ingested, reduced self-administration of nicotine in addicted rats by 64 percent.

Now Savant HWP, a pharmaceutical company in California, has developed a drug called 18-MC, a com-



Ibogaine extract and roots of the plant from which it is derived.

pound chemically related to ibogaine, which it hopes will produce the antiaddictive properties without triggering hallucinations. They are betting that the “trip” is not a necessary component of the therapy—an idea shared by some academics. In 2014 the company completed phase I trials in Brazil with 14 healthy volunteers to determine whether the drug is safe, which they do not plan to publish (as long as the data are provided to the FDA, no publication is required). Savant HWP CEO Stephen Hurst reports that overall the drug was “well tolerated” and there were “no serious adverse effects,” although it was “much more potent than we were expecting.” Phase II trials of the drug's efficacy are set to begin in the U.S. in early 2017.

Some hold out hope that ibogaine in its natural form could also become a standard treatment for addicts, but other experts urge caution. They warn that not enough is known about the risks of taking the drug, which has a long history of use in West Central African shamanistic rituals. Reported adverse effects include heart attack and seizures, and several people have died while seeking addiction relief with ibogaine.

Also mysterious is how ibogaine works to disrupt the cycle of addiction. People who have tried it have likened the intense hallucinogenic trip to going through years' worth of therapy in 24 hours, with flashbacks to childhood and pivotal experiences. “It was so vivid. It was like watching a movie with your eyes closed,” says Kevin (whose name has been changed to protect his identity), who tried ibogaine for multiple addictions during a stay at a clinic in Mexico. “I had visions of me being 16 years old when I used to drink cough syrup, and my mom caught me one night and she was crying.”

But experiences with ibogaine vary from person to person—not everyone, for instance, experiences the drug's trippy effects—and its neurochemistry and biophysics are perplexing. Research indicates that ibogaine acts on dopamine, serotonin and other neurotransmitter pathways strongly linked to addiction and reward, similar to other psychedelics currently being explored for addiction and mental illness treatment. Yet preliminary studies sug-

GETTY IMAGES (ibogaine); © ISTOCK.COM (pills icon)

gest that ibogaine attaches to other molecules in a unique way. “The mechanism of action at the molecular level is peculiar,” wholly unlike that of “traditional” drugs, says Emeline Maillet, a co-author of the 2015 study on rats and nicotine, who was then at DemeRx in Miami. Most active compounds work by binding to a receptor on the outside of a cell membrane. But ibogaine seems to do the opposite, binding to the inside of the membrane—something no other naturally occurring molecule is known to do, says Maillet, who observed this effect in another 2015 study examining ibogaine’s effect on opioid receptors.

Gary Rudnick, a professor of pharmacology at Yale University, observed a similar phenomenon in a 2016 study on ibogaine and serotonin, finding that ibogaine blocked cocaine molecules by binding to “inward-facing,” “mutually exclusive” locations on serotonin transporters. “All inhibitors except for ibogaine bind in an outward-facing configuration. So ibogaine is unique,” Rudnick says. But we are still far from knowing the truth about how the drug works, he adds: “Ibogaine has a lot of effects on many different proteins. It’s not a very clean drug. We’re not sure which targets are responsible” for its addiction-interrupting ability versus its other effects.

Experts emphasize that ibogaine treatment, which can cost up to \$10,000 on the black market, is not a cure. Relapse is likely in people who use ibogaine as their sole means of therapy without changing their other harmful patterns. Until we learn more about the drug’s mysterious effects and until safer versions become available, the best advice for people struggling with addiction is to follow proved methods, including cognitive-behavioral therapy, support groups and approved antiaddiction medication.

—Roni Jacobson



Are the Kids All Right?

People view the risks of leaving kids alone differently depending on the reason Mom left

Last September a man in Massachusetts posted a video on Facebook showing a baby alone in a car in a gas station parking lot. As the video went viral, commenters vigorously condemned the mother, despite her returning within three minutes. According to news reports, police charged her with reckless endangerment.

Such incidents—and attendant outrage—are not uncommon in the U.S., where a hodgepodge of state laws govern when parents may leave kids unattended. Cognitive psychologist Barbara Sarnecka of the University of California, Irvine, wondered if moral judgment, rather than rational concern, may play a part in the American attitude toward briefly leaving a child alone—a social norm that is not universally shared around the globe. A wealth of research on “motivated reasoning” suggests that people often adjust their beliefs to align with moral views.

To investigate, Sarnecka and her colleagues asked 1,501 participants to complete an online questionnaire in which they read about mothers leaving children between the ages of 10 months and eight years alone for short periods. Reasons for the mother leaving included everything from “unintentional” to “working” to “meeting an illicit lover.” Respondents rated the risk each scenario posed on a scale from 1 to 10.

According to the findings published in August 2016 in the journal *Collabra*, the raters reported the risk to the child as lowest if the reason was unintentional and highest if it was meeting a lover, despite the fact

that the child’s situation and danger level were identical. The risk ratings were strikingly high overall, with 10 being the most common answer. To make sure people were not just using the ratings to express disapproval, the researchers provided an outlet by asking them to make separate moral judgments, but this tactic only increased risk estimates.

The findings confirm that these risk judgments are indeed influenced by moral attitudes. Together with the high estimates across all situations, the results imply that a new social norm of “no child left alone” has come into force in the U.S. This norm “entrenches class privilege,” argues co-author P. Kyle Stanford, a professor of logic and philosophy of science. “Making sure children are supervised 24/7 is something only part of the populace can afford to do.”

This trend is not prevalent around the world, however. On a recent trip to Norway, lead study author Ashley Thomas says she noticed that people often leave infants in strollers parked outside shops or cafés while they nip in for lunch or coffee. This is seen as perfectly acceptable in most Scandinavian countries, where locals value the benefits of fresh air for children. In Japan children run errands and ride public transit without an adult. In fact, first graders sometimes wear yellow hats to school to make them easier for adults to look out for—the polar opposite of most U.S. parents’ attitude toward strangers. The team plans to look next at whether results vary among different respondent groups. —Simon Makin

Stop Sending Yourself Reminder E-mails

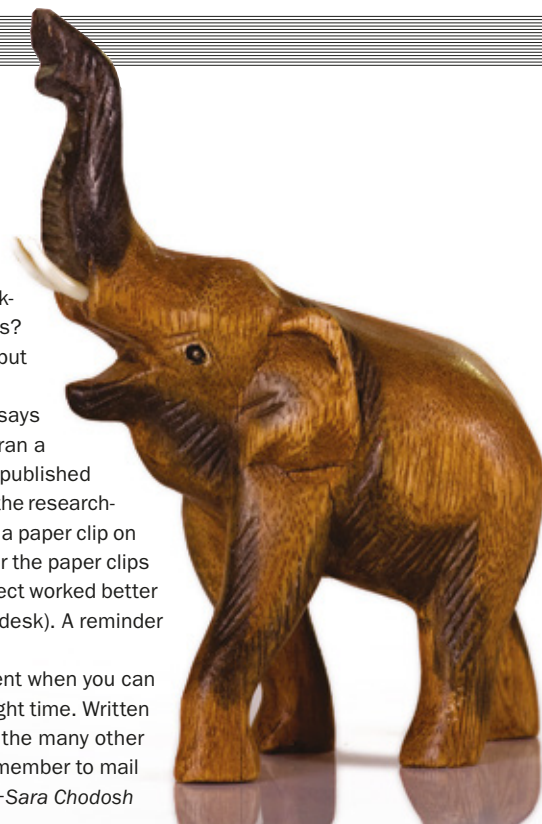
A physical object is a more effective way to jog your memory

Is your home littered with sticky notes telling you to mail that birthday card or pay that parking fine? Are your desk and computer similarly festooned with paper or digital reminders? Chances are, they are not very effective. Recent research suggests there is a better way: put an unusual object in a spot where it will catch your eye at the right moment.

“There are so many virtuous things we want to do that we don’t follow through on,” says behavioral scientist Todd Rogers of the Harvard Kennedy School of Government. Rogers ran a series of experiments to test what makes a reminder effective, the results of which were published in May 2016 in *Psychological Science*. In one experiment, participants who said they wanted the researchers to donate a dollar to charity were told to indicate that choice by remembering to pick up a paper clip on their way out of the laboratory. Those who were told to look for a small elephant statue near the paper clips were more likely to follow through. Subsequent experiments showed that the reminder object worked better when it was unusual or unique in its context (for instance, the only stuffed animal on the desk). A reminder picture on a computer screen worked in the same way.

For a reminder to succeed, Rogers says, it has to capture your attention at the moment when you can focus on the task. A string around your finger is always there, so it fails to cue you at the right time. Written reminders may be found at the right time and place, but they are often not distinct from the many other papers around us. If instead you place, say, a plush alien by your door and think, “I will remember to mail that card when I see the alien,” you may be more likely to complete the task.

—Sara Chodosh



The Cosmetics Conundrum

Women who wear makeup in the office may be judged differently by male and female co-workers

For women, wearing makeup at work can be a complex issue. They must balance looking professional with the risk of being objectified. Overall, research shows that use of cosmetics signals status. A new paper, published in October 2016 in *Perception*, examines how it projects success—while explaining some of its costs.

In the first of two experiments, researchers photographed 40 female college students with and without makeup and presented them to another group of 128 (mostly heterosexual) male and female undergraduates. The observers rated the pictures on “attractiveness” and two components of social status, “dominance” and “prestige.” The words were left undefined, but dominance typically refers to control over others through force or threat, whereas prestige is freely offered respect. In this study, women wearing makeup were seen by men (but not women) as more prestigious and seen by women (but not men) as more dominant. Vikto-



ria Mileva, a researcher at the University of Stirling in Scotland and the paper’s primary author, calls this asymmetry a “standout surprise.”

The researchers speculated that men tend not to see women as physically threatening, and so makeup should not affect their ratings of dominance. Women, on the other hand, might see their peers in makeup as sexually competitive and thus socially dominant. Meanwhile men might see women in makeup as prestigious because, as past studies show, attractive people are assumed to be competent. This positive “halo

effect” might be absent in female observers because they feel socially threatened.

The researchers conducted a second study to see if makeup really does trigger feelings of sexual competition. Forty-eight new female undergraduates evaluated the photos from the first study, answering questions such as “How jealous would you feel if this woman were to interact with your partner?” The participants judged women in makeup to be more attractive to men and more promiscuous and predicted they would feel more jealousy toward them.

“The idea that a woman is always suspicious of other women wearing makeup is a little over the top,” Mileva observes. “But in certain contexts there may be some cause for concern.” Reactions may be different in the real world and with older men and women. But we could all be more careful with the assumptions that we make about a woman’s appearance at work.

—Matthew Hutson

Can Treating Nightmares Prevent Suicide?

Nighttime terrors increase suicidal behavior independently of other risk factors

Suicide rates have been rising alarmingly in the U.S. and have reached a 30-year peak of 13 per 100,000 people, according to a 2016 report by the U.S. Centers for Disease Control and Prevention. As psychologists and public health officials scramble to find solutions, Michael Nadorff, a psychologist at Mississippi State University, argues that one treatable risk factor has been hiding in the dark: nightmares.

Over the past five years Nadorff's research has shown that nightmares are an important clue to suicide risk among healthy individuals—and that therapy aimed at addressing their nightmares could help save lives.

Scientists measure suicide risk by three elements: thoughts of suicide, suicidal behaviors and individuals' own beliefs about the likelihood that they will die by suicide. In a 2011 study published in the journal *Sleep*, Nadorff and his colleagues evaluated suicide risk in 583 undergraduates and then examined how symptoms such as anxiety, depression and nightmares were related to that risk. Not surprisingly, the researchers found that the more severe the symptoms, the higher the suicide risk. When they looked more closely, however, they found that having nightmares correlated with overall suicide risk more closely than any other factor.

"What amazed me was that not only are nightmares associated with suicide but the relation was maintained even after we controlled for depression, anxiety and PTSD [post-traumatic stress disorder]," Nadorff says. "So here are some of the biggest risk factors in the field people think of or assess for, but nightmares are adding something that the others are not capturing."

Nadorff expanded on these findings in 2013 in a study published in *Suicide and Life-Threatening Behavior*, when he showed that the longer a person experiences nightmares (in months), the higher the suicide risk. In 2014, in a paper published in the *Journal of Affective Disorders*, Nadorff looked at how nightmares related to the number of suicide attempts and, specifically, what factors distinguish those who stop at one suicide attempt from those who will try again. "Depression doesn't, anxiety doesn't, all these common risk factors are not differentiating," Nadorff remarks. Yet nightmares were linked to a fourfold increased risk of renewed attempts.

Other researchers have found similar results in other countries. The National FINRISK Study, a series of health surveys of the Finnish adult population, found that having frequent nightmares increased the risk for death by suicide more than twofold, according to data obtained by the Finland National Death Reg-



istry. A similarly large study from Sweden and a meta-analysis of 14 studies also showed that nightmares increase suicide risk.

In a 2014 study published in *Sleep* and conducted at the University of Pennsylvania, researchers found evidence that suicide is more likely to occur at night, especially between midnight and 6 A.M. And in a paper published in 2016 in *Sleep Medicine Reviews*, the same researchers proposed that just being awake at night increases the risk for suicide. Why? "One possibility is that being awake at night may be associated with increased utilization of alcohol and other substances, reduced social support, and easier access to weapons," the authors suggested in the 2016 paper. "Another possibility is that insomnia and/or nightmares contribute to suicidal ideation and behavior by intensifying the individual's sense of hopelessness, isolation, and distress relative to the inability to sleep." They concluded that targeted treatment for nightmares and insomnia should be incorporated into suicide prevention programs.

Most health care providers do not survey patients about nightmares, and most sufferers are unlikely to report them. Yet there are simple, fast and effective treatments, the most common being imagery rehearsal therapy (IRT), which focuses on modifying the nightmare through waking visualization. The first step is to imagine the nightmare and write it down before rewriting the story with a more desirable ending. This "happy" version of the nightmare is then visualized and rehearsed for 10 to 20 minutes during the day. The best part? This simple therapy can be effective at treating nightmares after only one to three sessions.

Still, suicide prevention remains a complex issue, and more work needs to be done to evaluate whether treating nightmares with IRT, in combination with existing interventions, can be effective, especially for those high-risk individuals who have already made one attempt.

—Michelle Carr

Tomorrow's Criminal Justice

Untapped human abilities and new technologies could identify criminals and fight crime

Despite advances in forensic techniques, criminal investigations still rely on age-old tools such as eyewitness testimony, which can be biased and unreliable. But what if we could take advantage of other human abilities, such as sense of smell or a talent for facial recognition? Researchers are exploring that possibility and other crime-fighting techniques that rely less on human judgment and more on big data crunching such as an algorithm that predicts an offender's risk of committing another crime. These approaches need to be validated before we put them to use, but research suggests they could be a boon to the criminal justice system.

Nosewitnesses

Imagine witnessing a crime and being called into a police station where a detective presents you with an array of human scents. Your task is to sniff out the one that belongs to the criminal. It's not such a crazy idea—you've heard of eyewitnesses and maybe even earwitnesses, but someday people might be able to serve as "nosewitnesses," too, research suggests.

In a study published in May 2016 in *Frontiers in Psychology*, Swedish and Portuguese researchers showed 73 men and women a video of a crime paired with a body odor, then presented them with an olfactory lineup containing three, five or eight different scents (including the one associated with the video). The participants correctly identified the culprit 96 percent of the time in three-suspect lineups. Unfortunately, their accuracy fell to 56 and 46 percent in five- and eight-suspect lineups, respectively. A second experiment tested how long 40 participants could remember crime-associated odors. Although they could do so for short periods, the memory was unreliable after one week. The researchers argue that nosewitness-

es perform similarly to eyewitnesses and earwitnesses. All forms of witness testimony are fallible, but scent-based lineups could prove especially useful for identifying perpetrators of crimes that bring them into close quarters with their victims, such as sexual assault, or crimes committed under cover of darkness.

—Jason G. Goldman

Super-Recognizers

Smell is not the only human sense that is underrated. People who are exceptional at remembering faces—so-called super-recognizers—are useful to police and border-control units because they can identify suspects seen in closed-circuit television footage or photographs. But what makes these individuals so good at remembering faces?

New research suggests that where and how super-recognizers focus their eyes may make a difference. In a study published in March 2016, researchers at

Bournemouth University in England recruited eight super-recognizers and 20 people with average face-recognition ability and tracked their eye movements as they looked at photographs of faces. The scientists found that compared with average volunteers, super-recognizers spent more time focusing on noses than on any other part of the face. Last May, however, some of the same researchers conducted an in-depth cognitive assessment of six laboratory-identified super-recognizers and reported in the journal *Cortex* that these individuals tend to process the entire face—including the spacing between features—rather than one specific feature at a time.

"Super-recognizers may have bigger perceptual spans and take in more information from looking at the center of a face," says Anna Bobak, a psychologist now at the University of Stirling in Scotland who co-authored both studies. In short, staring at the nose may help super-



recognizers better process the whole face.

The London Metropolitan Police has recently recruited a special squad of super-recognizers from within the force to help with identity-recognition tasks. But police are not the only ones who may benefit from this work—if additional studies confirm these findings, nose gazing may end up being a useful strategy to help “people who struggle with faces in their everyday life,” Bobak says.

—Melinda Wenner Moyer

Computer Judges

Another area of the criminal justice system that relies on human judgment is the arraignment—when a suspect has been arrested but not yet charged and a judge has to decide whether to release or lock up the alleged offender until his or her next court date. Legal experts and scientists alike have struggled for decades to bring a data-driven, empirical approach to tough legal decisions such as these. Now technology allows them to employ massive data sets and increasingly sophisticated statistical algorithms to do so.

Researchers at the University of Pennsylvania recently trained a machine-learning algorithm on nearly 29,000 domestic violence cases to see how it might perform. According to findings published in March 2016 in the *Journal of Empirical Legal Studies*, the method picked up connections between the likelihood that a suspect would reoffend after being released and variables such as age, gender, the number of prior charges and the number of prior arrest warrants. When faced with new, unfamiliar cases, the computer correctly identified suspects who did not go on to reoffend 90 percent of the time.

Today around 20 percent of those released after an arraignment are rearrested within two years. Although the software would not replace human judges, the researchers say that their algorithm could help cut the reoffender rate in half, to 10 percent, perhaps averting more than 1,000 domestic violence arrests every year for the average large U.S. city. —J.G.G.

In Human Attraction, You Are What You Eat

Women prefer the scent of men who eat diets rich in certain foods—including garlic!



When it comes to your love life, the impact of your diet could go beyond having a few extra pounds around the waist—what you eat may also influence how pleasing your body smells to members of the opposite sex. Scientists have long observed such a link in animal research—female salamanders are attracted to males that eat nutrient-rich diets, for example—and something similar may be true in humans, some preliminary studies suggest.

In a series of experiments published in 2016 in *Appetite*, 42 men snacked on raw garlic or swallowed garlic capsules, then wore cotton pads under their armpits for 12 hours. The same men also donated pads after wearing them on a garlic-free diet. The pungent samples were later evaluated by 14 women, who collectively rated the body odor of garlic eaters as more pleasant, attractive and masculine compared with that of men who did not ingest any garlic. The men needed to eat at least four cloves or one 1,000-milligram garlic-extract capsule to have a measurable effect. Because garlic enhances levels of antioxidants in the body and kills harmful bacteria, it could change the way our sweat smells, signaling healthiness to potential mates, the researchers hypothesize. “Women may also use cues in body odor to find a partner who can secure quality food,” says ethologist Jitka Fialová of Charles University in Prague, the study’s lead author.

Garlic is not the only food that might boost a man’s sex appeal. For a 2016 study published in *Evolution and Human Behavior*, psychologists at Macquarie University in Sydney, Australia, had several women rate the smell of T-shirts worn by 43 men for 24 hours. The men filled out questionnaires about the foods they ate, and researchers measured the yellowness of the men’s skin to gauge their consumption of carotenoids—pigments found in veggies and fruits such as pumpkins, carrots or apricots. Previous studies have found that carotenoid-induced yellowish skin is more visually attractive to potential partners—at least among Caucasians. In this study, the women reported the scent of men who indulged in carotenoid-rich foods to be fruity, sweet and particularly pleasant. These findings, too, could be explained by our evolved skills for finding healthy partners because low plasma carotenoid levels are associated with infection and greater mortality.

So how soon before a date should you pile on the garlic and veggies? Is it really going to sway things your way? And do men find women who eat the same diets as attractive? The jury is still out on these questions. One thing is certain, though—garlic breath is no aphrodisiac, so time your consumption wisely. —Marta Zaraska



How to Be a Better

spender

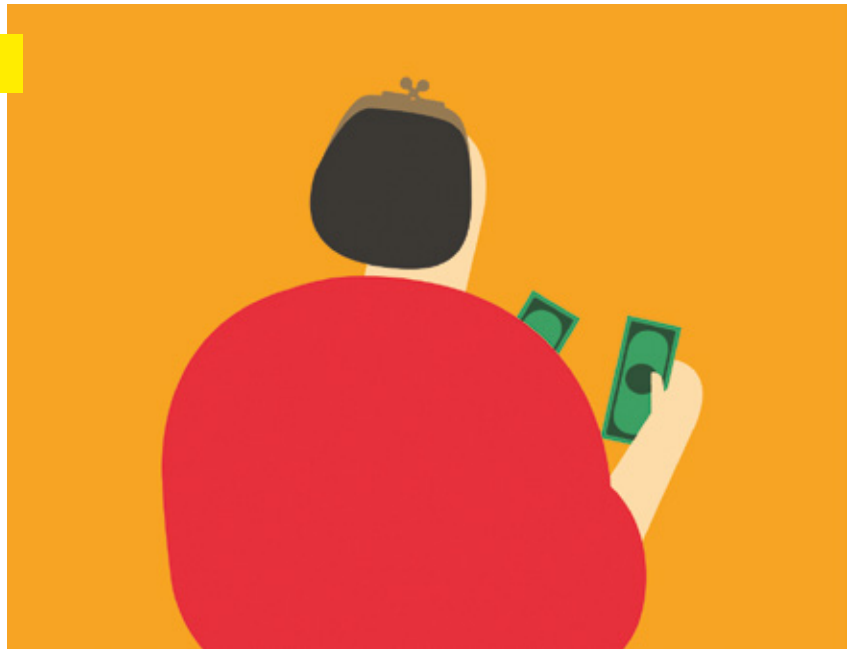
Our brand-new family budget is my best friend—and my nemesis. It has allowed me to work less so I can have time to pick up our kindergartner from school and cook dinners for my family, which I love. But it also forces me to go without things that I want, which I don't love. In fact, I hate it. I've been spoiled too long by a professional job, a two-income marriage, and our collective culture of credit cards and mass consumption. Practicing smart restraint doesn't feel natural to me yet, but I'm hoping that this advice, gleaned from experts in marketing and psychology research, will help me become a smarter, happier spender. Maybe it will help you, too.

#1 Beware the magpie effect.

Human beings are excited by shiny, new objects—and stores and car showrooms and Web sites are full of them, just sitting there, begging us to spend money on them. “New and different things grab our attention quickly,” says Elizabeth Dunn, a professor of psychology at the University of British Columbia and co-author of the book *Happy Money: The Science of Smarter Spending* (Simon & Schuster, 2013). Multiple functional MRI studies have shown that when humans see something new, the brain's “novelty center”—the *substantia nigra/ventral tegmental area* (SN/VTA)—becomes active. Just the anticipation of interacting with something novel sets off a cascade of SN/VTA activity, a 2007 study from University College London found.

That's why we have to arm ourselves with this knowledge when we feel compelled to spend on something new that we don't really need: what is new now will one day become old and much less exciting. “A new luxury car will make you happier for a while, but you'll adapt quickly to the heated seats and leather steering wheel that initially captivated your attention, and they'll fade into the background when you're racing to work in the mornings,” Dunn says.

#2 Buy yourself some time. A smart use of your funds is something that gives you the gift of time, Dunn says. In a study published in April 2016 in *Social Psychological and Personality Science*, Dunn and her colleagues found that peo-



ple who value time over money report higher levels of happiness and satisfaction with life. “Maybe you're buying a Roomba vacuum for the house so you won't have to spend your Saturday afternoons vacuuming,” Dunn says. “But if you're buying your fifth pair of black heels? We would argue that using your money to improve how you spend your minutes and seconds of the day is one of the most direct routes to happiness.”

#3 Spend when you're smiling. Lots of people shop when stressed-out or unhappy—so many, in fact, that “retail therapy” has an entry in the *Oxford English Dictionary*. The phenomenon isn't recognized by the *DSM-5*, the most recent edition of the *Diagnostic and Statistical Manual of Mental Disorders*, psychiatry's “bible,” but research suggests we shouldn't ignore it. Studies by psychologist Jennifer Lerner, co-founder of the Harvard Decision Science Laboratory, have shown that sadness increases consumption, both of goods and food. Not only that, but in a 2008 study in *Psychological Science*, she reported that feeling blue also makes people willing to pay higher prices. Lerner and her colleagues have labeled this the “misery is not miserly effect.” Perhaps this explains my Zappos.com order of luxurious leather boots, placed in the middle of a nerve-racking night. (Needless to say, the boots went back.)

#4 Ignore price (sort of). It's not that we shouldn't take advantage of price breaks or comparison shop, but we should be careful of “sales” as a matter of course, says psychologist Kit Yarrow, author of *Decoding the New Consumer Mind* (Wiley, 2014). “As an ethnographer, I spend a lot of time looking under beds and in the backs of closets for what *didn't* work for the shopper—a ‘mispurchase,’ you might say,” she says. “I find a lot of sale merchandise there. This might be something that turned out to be the wrong color, wrong size or wrong flavor, but it was the right price. They aren't really things the shopper wants or needs. They're purchased for the glory of getting a great price.”

I'm a sucker for a sale, and I have wasted a ton of money over the years on a bunch of useless stuff. But perhaps this last piece of advice from the wise Dr. Yarrow will help keep me from slipping back into old spending habits the next time I see a “50 percent off!” sign: “Focus on what you're giving up, not just what you're getting. Often shoppers get so excited about a bargain, they lose sight of what they're spending—and what they could be buying instead.”

Skipping the boots, for example, could fund a whole date night alone with my husband. And for parents of two young kids, that's truly priceless.

—Sunny Sea Gold

For Arachnophobia, a New Twist on Exposure Therapy

Seeing photos of these eight-legged nasties soon after being reminded of your phobia could destabilize fear memories

The sight of a spider casts dread into some people's hearts. This fear, known as arachnophobia, is perturbing, irrational and debilitating. But at its essence, fear is rooted in memory, and memory is plastic.

For years the mainstay treatment for phobias has been exposure therapy—gradually familiarizing a patient with the source of his or her fear by repeatedly presenting it in a safe environment. A related approach aims to disrupt the fear memory itself. In a study published in August 2016 in *Current Biology*, a team of researchers in Sweden successfully did just that with chronic arachnophobia sufferers.

The researchers showed 45 arachnophobes photographs of spiders for several seconds to trigger their fear. Half the participants were shown images of these arthropods again 10 minutes later; the other half saw them again after six hours. Functional MRI revealed increased activity in the basolateral amygdala—a brain region that responds to scary stimuli—when subjects in both groups were looking at the creepy crawlers. On seeing the pictures again, however, the 10-minute-interval group had lower amygdala activity than the six-hour

group and avoided spider images less in behavioral tests days later.

The key to this difference may lie in how memory works. When subjects first see the photos and are reminded of their fear, the memory “destabilizes, and it has to be resaved,” says Johannes Björkstrand, a psychologist at Uppsala University who led the study. Subjects in the 10-minute-interval group did not have enough time to resave their fear memory, he says, before being shown more spider pictures, whereas the other subjects had plenty of time and retained their original fear.

Memory-disruption therapy might one day be used in the clinic. For example, patients would be reminded of their fear for one minute and, 10 minutes later, would receive three hours of exposure. This could be repeated over several sessions, as with traditional exposure therapy. Larger, longer-term trials are needed to determine if the method works better than standard exposure therapy. If successful, the researchers say the treatment could be investigated for other phobias, as well as post-traumatic stress disorder and related anxiety disorders.

—Abdul-Kareem Ahmed



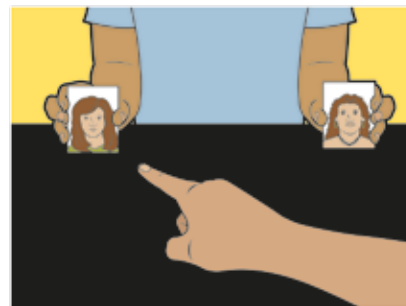
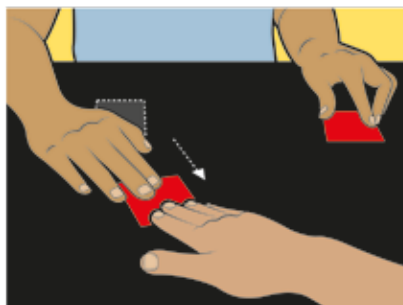
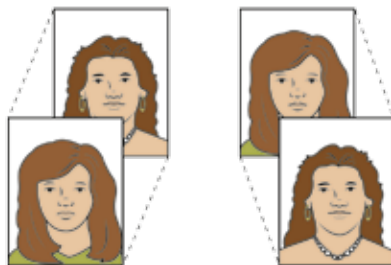
GETTY IMAGES

Take Your Pick?

Cognitive scientists and magicians know that free choice can be an illusion

We think we know what we want—but do we, really? In 2005 Lars Hall and Petter Johansson, both at Lund University in Sweden, ran an experiment that transformed how cognitive scientists think about choice. The experimental setup looked deceptively simple. A study participant and researcher faced each other across a table. The scientist offered two photographs of young women deemed equally attractive by an independent focus group. The subject then had to choose which portrait he or she found more appealing.

Next, the experimenter turned both pictures over, moved them toward the



subjects and asked them to pick up the photo they just chose. Subjects complied, unaware that the researcher had just performed a swap using a sleight-of-hand technique known to conjurers as black art. Because your visual neurons are built to detect and enhance contrast, it is *very* hard to see black on black: a magician dressed in black against a black velvet backdrop can look like a floating head.

Hall and Johansson deliberately used a black tabletop in their experiment. The first photos their subjects saw all had black backs. Behind those, however, they hid a second picture of the opposite face with a red back. When the experimenter placed the first portrait face down on the table, he pushed the second photo toward the subject. When participants picked up the red-backed photos, the black-backed ones stayed hidden against the table's black surface—that is, until the experimenter could surreptitiously sweep them into his lap.

The first surprise was that the image switches often went undetected: Hall and Johansson reported that their subjects realized that the photo they picked up was

not their actual choice only 26 percent of the time. Then came an even bigger shock. When the researchers asked the participants to explain their selection—remember, they *chose* the other picture—they did not falter: “She’s radiant. I would rather have approached her at a bar than the other one. I like [her] earrings!” a subject said, even though the woman he actually chose had no earrings. Pants on fire.

Over and over, the participants made up just-so stories to account for their nonchoices. Instead of pondering their picks first and then acting on them, the study subjects appeared to act first and think later. Their improbable justifications indicate that we can use hindsight to determine our own motives—just as we might speculate about what drives someone else’s behavior after the fact. In their now classic paper, Hall and Johansson dubbed this new illusion “choice blindness.”

Choice blindness reveals that not only are our choices often more constrained than we think, but our sense of agency in decision making can be a farce in which we are the first to deceive ourselves. Here we present a few other examples. **M**



BY SUSANA MARTINEZ-CONDE AND STEPHEN L. MACKNIK

Susana Martinez-Conde and Stephen L. Macknik are professors of ophthalmology, neurology, physiology and pharmacology at SUNY Downstate Medical Center in Brooklyn, N.Y. They are authors of *Sleights of Mind*, with Sandra Blakeslee, winner of a Prisma Prize for best science book of the year (<http://sleightsofmind.com>), and magician members of the Academy of Magical Arts (aka the Magic Castle in Hollywood) and the Magic Circle (in London).



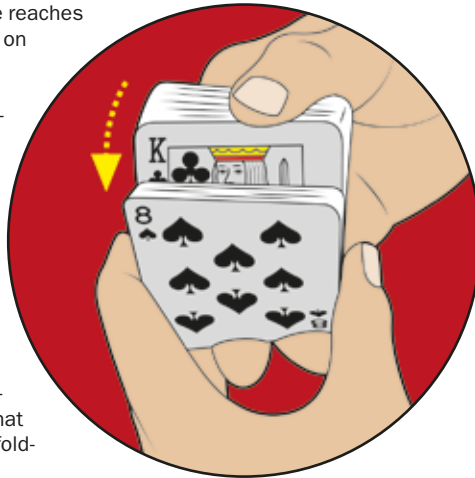
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FORCING THE ISSUE

It's a famous trick: A magician asks a member of the audience to join him onstage. With a flourish, he presents the volunteer with a fan of playing cards and asks him or her to pick one. The spectator points. "Are you sure that's the card you want?" the magician asks. "Would you prefer the card to its left or right? The choice is yours." The spectator makes a seemingly free choice onstage that somehow ends up playing a critical part in the magician's grand finale.

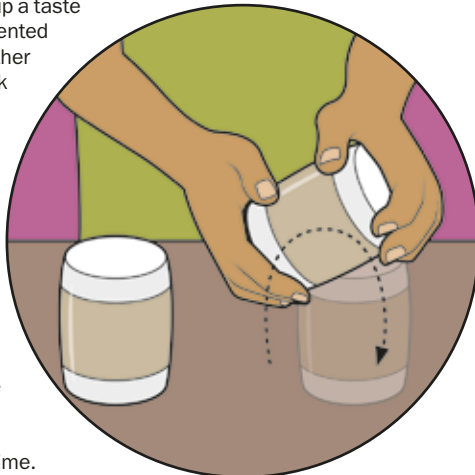
Did the magician know in advance how the spectator would choose? Or was the choice predetermined in another way? For centuries, magicians—using a technique called forcing—have known how to secretly impose their own choices onto a spectator's. In a recent study, neuroscientists at the University of Buenos Aires and the Institute of Neurosciences of Alicante in Spain found that naive subjects participating in an experiment—which was presented as a magic show—felt just as free about choices forced on them as those they actually made.

The experiment used two methods, classical forcing and visual forcing. (Spoiler alert! Stop reading now if you do not want to learn how it works.) In classical forcing, the magician uses timing to force a specific card on the spectator. For instance, the magician will handle a deck of cards, presenting one card at a time, such that the "forced" card is closest to the spectator's fingers at that moment he or she reaches to grab one. Visual forcing relies on principles that are well known to visual scientists and psychologists in the lab. Onstage, a magician will riffle a deck of cards in front of a spectator's eyes and ask him or her to choose the card that produced the clearest mental picture. In fact, only one or two cards in the deck will have been clearly visible by virtue of their placement (the last couple of cards in the deck will have been most discernible) or longer exposure (the magician can ensure that a card is seen longer by slightly folding it, for instance).



TASTE CHALLENGE

In 2010 Hall and Johansson set up a taste test at a supermarket. They presented shoppers with two samples of either jam or tea and asked them to pick a favorite. Then they secretly flipped the containers over and offered one more taste of the favorite, which was, in fact, not what had been chosen. (The containers had two compartments, with openings at the top and bottom.) When asked to explain their "decision," the shoppers pointed out the switcheroo only a third of the time. Even when the options were as distinct as sweet cinnamon apple and bitter grapefruit, they noticed the switch only half the time.



ROCKING THE VOTE

In a subsequent experiment, published in 2013, Hall and Johansson set out to change political attitudes during a general election in Sweden using choice blindness techniques. Study participants stated their voting intentions for the upcoming election and filled out a survey, revealing their attitudes toward hot-topic issues under debate by Sweden's left- and right-wing coalitions. Then the researchers once more used sleight of hand to alter the respondents' replies, presenting them with the opposite political views to their own. When invited to explain these doctored survey responses, 92 percent of the participants accepted and endorsed them! Moreover, almost half of the respondents indicated a willingness to consider changing their vote, based on the manipulated results—a much higher percentage than the 10 percent of voters who were prone to swing according to established political polls.

MORE TO EXPLORE

- **Failure to Detect Mismatches between Intention and Outcome in a Simple Decision Task.** Petter Johansson et al. in *Science*, Vol. 310, pages 116–119; October 7, 2005.
- **Magic at the Marketplace: Choice Blindness for the Taste of Jam and the Smell of Tea.** Lars Hall et al. in *Cognition*, Vol. 117, No. 1, pages 54–61; October 2010.
- **Choosing in Freedom or Forced to Choose? Introspective Blindness to Psychological Forcing in Stage-Magic.** Diego E. Shalom et al. in *PLOS ONE*, Vol. 8, No. 3, Article No. e58254; March 13, 2013.
- **How the Polls Can Be Both Spot on and Dead Wrong: Using Choice Blindness to Shift Political Attitudes and Voter Intentions.** Lars Hall et al. in *PLOS ONE*, Vol. 8, No. 4, Article No. e60554; April 10, 2013.

INTERVENTION

Is Mental Health Declining?

Recent data show that mental disorders are not improving and that diagnoses may be on the rise

By Edmund S. Higgins

The 1990s and 2000s were glorious decades to be a psychiatrist. It seemed as though each year several new, potentially life-changing medications were brought to market. Options became available to tackle long-standing, treatment-resistant disorders. It did not hurt that big pharma had deep pockets to promote the new offerings. Stigmas were falling, more people were seeking help than ever before, and just about any psychiatrist could brag about patients who, with the right medication and a little time, returned looking more confident and reporting fewer symptoms.

Today the shine has dimmed. The mental health of the nation may have even declined in the past 20 years. This trend is what Thomas Insel, former director of the National Institute of Mental Health, calls one of the “inconvenient truths” of mental illness. Suicide rates per 100,000 people have increased to a 30-year high. Substance abuse, particularly

EDMUND S. HIGGINS is a clinical associate professor of psychiatry and family medicine at the Medical University of South Carolina.



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of opiates, has become epidemic. Disability awards for mental disorders have dramatically increased since 1980, and the U.S. Department of Veterans Affairs is struggling to keep up with the surge in post-traumatic stress disorder (PTSD).

The most discouraging assessment came in 2013 from an in-depth analysis by the U.S. Burden of Disease Collaborators. Hundreds of investigators gathered data on 291 diseases and injuries between 1990 and 2010. Combining premature death and disability to calculate the burden of each disease, they found that the toll of mental disorders had grown in the past two decades, even as other serious conditions became more manageable.

More people are getting treatment and taking medications today than ever before, so what is going on? I would argue that a lack of precision and objectivity in diagnosing and treating mental illness has stalled our progress. We must embrace new strategies in research and prevention to move forward.

The Inconvenient Truth

The American Psychiatric Association, the American Psychological Association and big pharma explain the de-

terioration of mental health nationally by proposing that not enough people are getting treatment. But this suggestion seems a bit self-serving.

Another explanation points to the vague nature of psychiatric diagnoses. Social Security awards for disability have exploded in two areas: musculoskeletal and mental disorders, both of which are often diagnosed on the basis of a patient's subjective reports rather than hard measures such as scans or blood tests. Furthermore, both seem to expand and contract with the economy. Thus, changes in the prevalence of mental disorders may not necessarily reflect changes in the biology of mental illness.

It is also possible that we are hampered by not having new treatments for patients seeking help. As it turns out, drugs developed in the past 20 years perform like older medications. Abilify is no more effective for treating schizophrenia than the very first antipsychotic, Thorazine. New antidepressants lift mood no better than the tricyclic antidepressants discovered in the 1950s. Lithium, first used in 1949, remains the gold standard for bipolar disorder. Adderall provides no further advantages for attention-deficit/

hyperactivity disorder than the Benz-drine first administered for it in 1937.

There are exceptions—we appear to be better at treating the depressive phase of bipolar disorder, and Clozaril is a more effective treatment for schizophrenia than its predecessors—but much of what seemed so revolutionary 20 years ago was more illusion than substance. The new medications tap into the same brain mechanisms as the old ones, albeit with fewer side effects. Finding novel treatments for mental illness has become so discouraging that several pharmaceutical companies have shut down or reduced neuroscience research.

The problem is that the brain is exceedingly complex. Behavior, emotions and cognition are manifestations of networks of cells that are turned on or off at the right time. The capacity to affect specific cells in the brain without altering other cells remains a massive challenge.

Finding New Solutions

Australia is experiencing the same problem as the U.S.: more people have access to treatment than ever before, but national mental health has not improved. In a 2014 discussion of the dilemma, psychiatric researcher Anthony F. Jorm of the University of Melbourne argued that prevention could be the best response, citing numerous studies of preventive interventions. For example a 2011 Cochrane review—a top-quality, multistudy analysis—revealed that teaching cognitive-behavioral therapy skills in the classroom can help reduce the incidence of depression among students.

Taking prevention one step further, Insel has advocated for research initiatives to discover biomarkers for mental illness. Laboratory tests or genetic markers that can identify at-risk individuals might allow us to intervene early, before symptoms begin.

In addition, it is paramount that we discover new mechanisms to treat mental illness. This progress will not come quickly—the brain does not give up its secrets

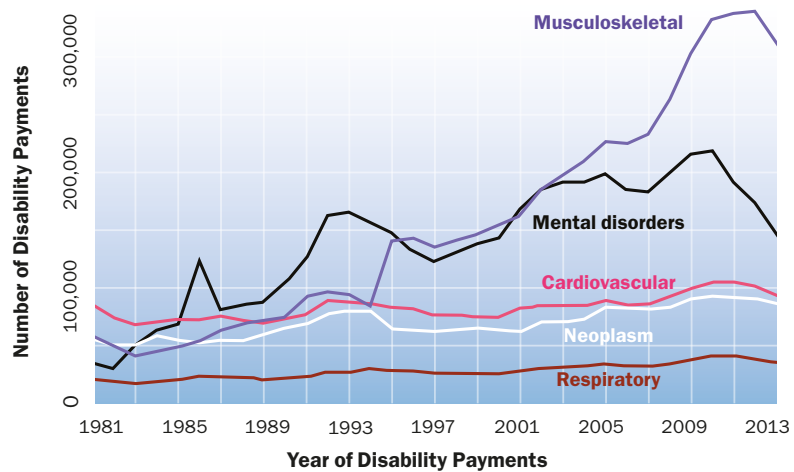
easily. But there is one unique, promising treatment that is struggling to get approval: psychedelic-assisted psychotherapy. Preliminary evidence suggests that drugs such as LSD and psilocybin could be used episodically, together with psychotherapy, to enhance the healing process.

The best evidence so far is with MDMA, also known as ecstasy, for people with PTSD. In a 2016 review, Mi-

ical use and a high potential for abuse,” which makes them hard for scientists to access. Big pharma has little interest in studying these molecules because most cannot be patented, and the government is not currently funding such research.

None of this is to say that mental health workers and their patients should stop what they are doing. We all have success stories to tell. As psychiatrist Peter D.

The Rising Toll of Mental Illness



Over the past two decades mental illness has become the second most common cause of disability in the U.S., as measured by Social Security disability claims. Only musculoskeletal disorders have risen faster, although both have tapered off with the improving economy.

chael C. Mithoefer, a Medical University of South Carolina psychiatrist, and his colleagues identified encouraging results from two phase II clinical trials in which people who received therapy supplemented with MDMA at just two or three sessions had fewer symptoms than those given therapy and a placebo.

Unfortunately, the Drug Enforcement Administration classifies psychedelics as drugs with “no currently accepted med-

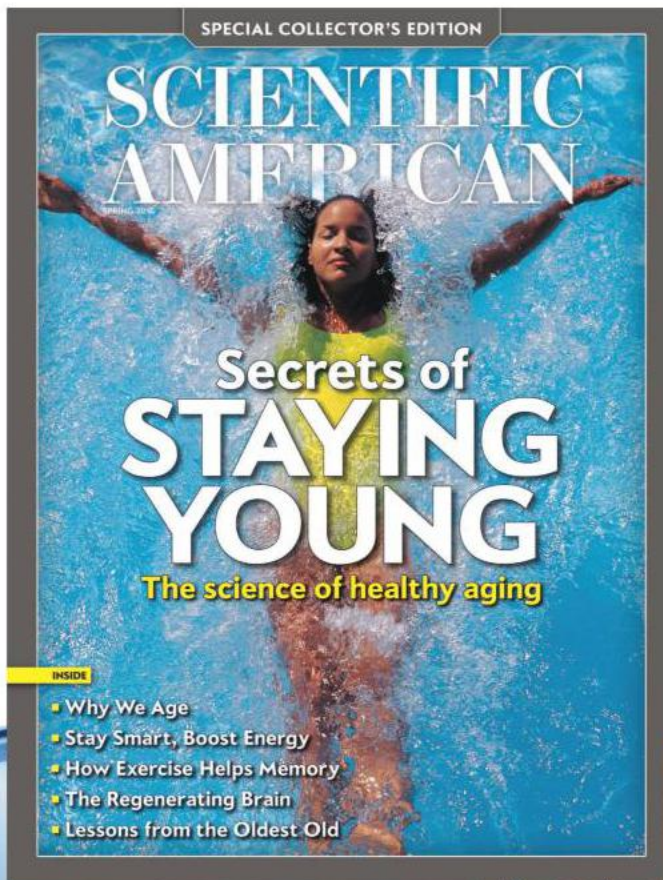
Kramer points out in his new book *Ordinarily Well* (Farrar, Straus and Giroux), the advent of today’s antidepressants has largely eliminated the immobilizing melancholy that was once all too common. Based on my own clinical experience, mental health treatment does improve symptoms and quality of life by about 20 to 40 percent for most patients. That’s a whole lot better than nothing but not nearly good enough. **M**

MORE TO EXPLORE

- **Why Hasn’t the Mental Health of Australians Improved? The Need for a National Prevention Strategy.** Anthony F. Jorm in *Australian & New Zealand Journal of Psychiatry*, Vol. 48, No. 9, pages 795–801; September 2014.
- **Novel Psychopharmacological Therapies for Psychiatric Disorders: Psilocybin and MDMA.** Michael C. Mithoefer, Charles S. Grob and Timothy D. Brewerton in *Lancet Psychiatry*, Vol. 3, No. 5, pages 481–488; May 2016.

SOURCE: ANNUAL STATISTICAL REPORT ON THE SOCIAL SECURITY DISABILITY INSURANCE PROGRAM, 2013. SOCIAL SECURITY ADMINISTRATION, DECEMBER 2014

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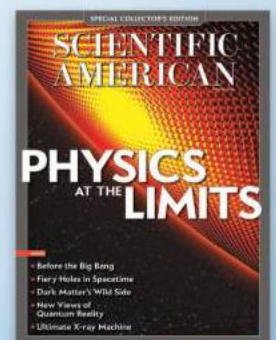
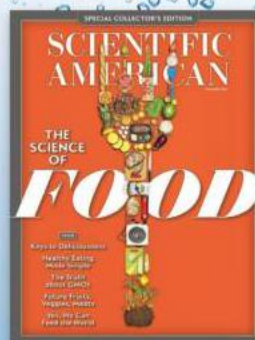


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“I can’t control myself,” he admitted.

“A couple of nights ago after another cocaine binge, I had the thought that I’d be better off dead than alive, and that’s when I called you.”



ILLUSTRATIONS BY MATT HARRISON CLOUGH

A Hidden Force of Habit

Abuse of cocaine, alcohol and pills was the patient's obvious problem, but at its root was undiagnosed ADHD


By Sean X. Luo

Myles* was an appealing young man: good-looking, engaging, mild-mannered, with a self-deprecating sense of humor. He was also one of my sicker patients, using cocaine, alcohol and the anti-anxiety drug Xanax in large quantities.

He was on a temporary leave of absence from work at a high-profile financial services company. When he was still

working, on a typical Friday night, he would go out with colleagues, call his dealer at 8 P.M. and begin drinking at 10 P.M. By midnight, when the cocktails led to stupor, he would start snorting lines of cocaine. The ebb and flow of the high floated him for the rest of the night. Occasionally he got into a fight. Sometimes he had reckless sex. The next

SEAN X. LUO, M.D., Ph.D., is a clinical psychiatrist in New York City and a researcher in clinical neuroscience and substance abuse at Columbia University.

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*Not the patient's real name.

ADHD AND ADDICTION

ADHD is diagnosed in about 11 percent of children and 4 percent of adults in the U.S.

Among adults who have substance use disorders, the prevalence of ADHD is much higher: 20 to 30 percent

morning he would feel profoundly guilty and sad, and he often took a few tabs of Xanax to “sleep it off.” The next night he would resume the cycle. These binges would last two to three days, costing him \$500 or more a day in cocaine alone. During the workweek he would get intense cocaine cravings, and he would do more lines at home by himself. He knew he needed sleep—on sleepless nights he would ply himself with alcohol before crashing, sometimes still in his suit.

People at work started to notice. Cocaine withdrawal symptoms—anxiety, irritation and fatigue—plagued him on business trips and in the office. Feeling nervous, he took Xanax before his performance review and nodded off in front of the boss. It was obvious that he needed help, and his employer told him to take some time off.

“I can’t control myself,” he admitted when he showed up in my office in New York City. “A couple of nights ago after another cocaine binge, I had the thought that I’d be better off dead than alive, and that’s when I called you.”

Myles did not land in this dire place in one day. When he started his job a few years earlier, he was excited by the big paycheck and titillating world of high finance. But the 80- to 100-hour workweek crushed him: he found it increasingly difficult to focus on the

details of a presentation, especially at 2 A.M., when he was working to meet an 8 A.M. deadline set by someone in another time zone. He had trouble wrapping up projects—he would dive in enthusiastically, working on a spreadsheet or PowerPoint deck, only to procrastinate when the details got too tedious. His work was littered with neglectful errors, and he began to worry about being fired.

It was around this time that he was first exposed to cocaine. One of his colleagues tempted him to use it one late night at the office. Initially he did not notice the high but only felt calmer and carried on work duties effortlessly into the night. He had a hunch that cocaine could help him stay up longer and be more productive, and he attributed his escalating use to the hours that piled on that winter. He was still coping comfortably on the surface, and his performance was deemed to be rapidly improving at his midyear evaluation.

But things fell apart and his cocaine use surged when his longtime girlfriend, who lived in California, decided to break up with him. Since he started his leave

from work—a few weeks before I saw him—Myles had tried to cut back. He managed to give up drinking and Xanax, but the cocaine cravings ceaselessly pulled at his mind, until he capitulated.

Dopamine Drive

We understand substance use disorders today as a condition in which drugs essentially hijack the brain. Patients are often fully aware of the risks, but craving and withdrawal symptoms override their efforts to take control. The intense craving, the sensation of a “high,” the compulsion to procure and use drugs, and the dysphoric state of withdrawal are all associated with a critical neurotransmitter released in the brain: dopamine [see “The Currency of Desire,” on page 48]. Dopamine signals the presence of rewarding and reinforcing stimuli, and cocaine prevents the brain from reabsorbing dopamine. The excess dopamine throws the brain into a state of imbalance: a circle of use, dopamine release and depletion, then craving, withdrawal and relapse.

A less well-known part of the story is



SOURCES: CDC (ADHD in children); NATIONAL INSTITUTE OF MENTAL HEALTH (ADHD in adults); HOWARD SCHUBINER IN CNS DRUGS, VOL. 19, NO. 8; AUGUST 2005 (ADHD in substance misusers)

that dopamine not only mediates reward, it also has important functions in maintaining focus and motivation. Dopamine is released not only in the limbic system, the part of the brain that evaluates and predicts reward, it is also released in the frontal cortex, which oversees attention and other executive functions. When the brain does not respond to dopamine optimally or does not release dopamine at the right time and place, people will experience cognitive difficulties such as poor concentration, listlessness, lack of patience and a tendency to make careless mistakes. When these symptoms are present early in childhood, they are recognized as signs of attention-deficit/hyperactivity disorder (ADHD).

People with ADHD often develop substance use disorders, perhaps in an attempt to self-medicate. Conversely, an estimated 20 to 30 percent of substance misusers have underlying ADHD (versus about 4 percent of adults in the general population). The exact reasons for this overlap are still unknown and probably vary by individual but most likely trace back to common problems in the dopamine system. Even so, patients with substance use disorders are often underdiagnosed for ADHD because clinicians do not routinely think of connecting the two conditions. And yet not recognizing and treating ADHD in such patients can make it more difficult for them to achieve abstinence and avoid relapse.

A Root Cause

To accurately diagnose Myles's possible ADHD symptoms, I called his parents and used the diagnostic interview for ADHD in adults. Evaluating when and what symptoms started early is an important consideration in consolidating the ADHD diagnosis. Myles's parents told me he was "absent-minded" and "fidgety" as a youngster. Because he

was so bright and did well in school, though, they never had any concerns.

My in-depth review revealed that Myles's ADHD symptoms and substance use problems both started early. In adolescence, he often felt distracted and irritable at school; for a while, he smoked marijuana daily, which helped to lessen these symptoms. He was able to "coast" because his schoolwork did not require his sustained attention. In college, he would occasionally "borrow" an Adderall—a psychostimulant drug used to treat ADHD—from friends to help him push through more challenging assignments. "It always made me feel calmer," he said, "which should've given me a clue."

Nevertheless, when I finally made the diagnosis of ADHD and suggested a course of prescription medication, Myles was hesitant. "Doc, I'm trying so hard to come off of cocaine," he petitioned. "Are you really going to put me on something that may be addictive?"

He echoed a common concern among clinicians and patients that psychostimulants, such as Adderall and Ritalin, while excellent treatments for ADHD, can themselves be addicting. In fact, evidence suggests that newer long-acting versions of these medications are safe and effective for ADHD and only rarely habit-forming. In addition, recent studies, including a 2015 investigation by Frances R. Levin of Columbia University and her colleagues, suggest that robust doses of a psychostimulant can not only improve ADHD symptoms but also help people quit addictive substances and prevent relapse, especially for cocaine.

After we thoroughly discussed the pros and cons, Myles agreed to a course of extended-release Adderall capsules. We combined it with a standard cognitive-behavioral therapy (CBT) program, targeting cocaine use disorder. Because

he is so motivated, Myles was a pleasure to work with—diligent with his CBT homework assignments, conscientious in his effort to cut ties with his dealer, and he always took his medications on time. We also treated his withdrawal symptoms with safer alternatives than alcohol and Xanax, such as clonidine and gabapentin. After one month of this treatment, Myles was drug-free but still had occasional cravings. We decided to continue with ongoing psychotherapy sessions, and we were optimistic that he could stave off relapses when work pressure resumed again, as it soon did.

Myles's treatment success is not atypical. Contrary to popular belief, a large proportion of patients with even the most severe substance use disorders can achieve abstinence. Relapse is common and part of the recovery process and, though serious, is not a sign of hopeless addiction. For Myles and many others, recognizing ADHD symptoms and successfully treating them can be crucial steps in breaking the cycle. **M**

MORE TO EXPLORE

- **Misuse and Diversion of Stimulants Prescribed for ADHD: A Systematic Review of the Literature.** Timothy E. Wilens et al. in *Journal of the American Academy of Child & Adolescent Psychiatry*, Vol. 47, No. 1, pages 21–31; January 2008.
- **ADHD, Substance Use Disorders, and Psychostimulant Treatment: Current Literature and Treatment Guidelines.** Scott H. Kollins in *Journal of Attention Disorders*, Vol. 12, No. 2, pages 115–125; September 2008.
- **Extended-Release Mixed Amphetamine Salts vs Placebo for Comorbid Adult Attention-Deficit/Hyperactivity Disorder and Cocaine Use Disorder: A Randomized Clinical Trial.** Frances R. Levin et al. in *JAMA Psychiatry*, Vol. 72, No. 6, pages 593–602; June 2015.

From Our Archives

- **ADHD Grows Up.** Tim Bilkey, Craig Surman and Karen Weintraub; January/February 2014.



HEAD STRONG

For many people with depression, exercise may be the most effective, least expensive and safest treatment

By Ferris Jabr

PHOTOGRAPH BY AARON GOODMAN

On Valentine's Day 2014 Elizabeth Droge-Young admitted herself to a hospital in Syracuse, N.Y. For more than a year, she had been struggling with depression—not eating well and losing interest in the movies, books and music that usually delighted her. She had withdrawn from her friends and was routinely missing classes at Syracuse University, where she was a fifth-year graduate student in evolutionary biology. Some days that winter she could not even make it out of bed, despite the fact that she had started taking antidepressants the previous fall. In her darkest moments, obsessive and frightening thoughts of self-harm and suicide flooded her mind. “It was horrible,” she recalls. “I felt very unsafe.” She realized she needed a serious intervention.

After a week and a half on suicide watch at the hospital, plus a stronger cocktail of medications, Droge-Young returned home, taking an academic leave of absence for the remainder of the school year. For a while, she seemed to be getting better. But when she went back to school in August, the unbearable sadness and dark impulses resurfaced. This time she turned to a hospital in Saratoga Springs, N.Y., some two and a half hours away, which offered a more holistic treatment. In addition to medication and counseling, her doctors prescribed a full schedule of daily activities, such as arts and crafts and walks around the grounds. During her stay, a hospital therapist also recommended exercise. So after her release, Droge-Young started going to the gym three to five times a week, walking and jogging on the treadmill, lifting weights and attending Zumba, a popular dance fitness class.

“It was empowering,” says Droge-Young, now 33 and working as a freelance science writer in Providence, R.I. “It really helped with my mood. There’s something wonderful about the mind-body connection exercise provides. Us-

Can a steady routine of physical workouts keep psychological disorders in check? In the case of depression, the answer is an emphatic yes.

ing weight machines or jogging on the treadmill allows you to be self-reflective: ‘Look at the strength and endurance I have. This is something positive about myself.’ And the dancing was joyful—just being able to move around in a way that was free and felt good.” Since incorporating exercise into her regimen for managing depression, Droge-Young has never relapsed to the point of requiring another hospitalization. To this day, she considers dance and riding on a stationary bike to be a crucial component of her treatment.

The fact that exercise improves physical health is so well known as to be a platitude. Decades of research demonstrate that regular exercise lowers the risk of many illnesses—heart disease, obesity, diabetes, cancer—and extends the average life span. In contrast, the benefits of exercise for mental health are not quite so obvious or well publicized. We work out to “get in shape,” and some of us depend on bike rides, neighborhood jogs or yoga to help clear our mind and relieve stress. But how often do we seriously consider exercise as a viable treatment for mental illness, one just as effective as medication or counseling? Can a steady routine of physical workouts really help to keep psychological disorders in check?

In the case of depression, the collective evidence to date suggests that the answer is an emphatic yes. Exercise is by no means a panacea, and in severe cases of depression, it may be futile on its own. But scores of experiments now show that exercise is much more than a temporary distraction from mental woes or some ultimately inconsequential palliative. It appears to

combat depression in a number of ways: by strengthening our biochemical resilience to stress, encouraging the growth of new brain cells, bolstering self-esteem and possibly even counterbalancing an underlying genetic risk for mental illness. For most people with mild to moderate depression, exercise is one of the strongest, safest, most practical, most affordable and even enjoyable treatments available.

“I am a big believer in the value of physical activity,” says clinical psychologist James Blumenthal of Duke University. “The majority of evidence suggests that a certain subset of patients can benefit just as much with exercise, if not more, than with medication.” Psychiatrist Madhukar Trivedi of the University of Texas Southwestern Medical Center, who has studied the relation between exercise and mental health for more than 15 years, agrees: “We have now generated a whole big body of literature about exercise as a treatment for depression. We’ve looked at dose, at adding exercise as an augmentation treatment, at specific biomarkers associated with improvement. We have the studies to show that something really powerful and interesting is going on.”

On the Strength of the Evidence

Major depression—an illness characterized by a persistent low mood or loss of interest in typically pleasurable activities, often accompanied by insomnia, fatigue, poor concentration or feelings of worthlessness—is one of the leading causes of disability and death around the globe, according to the World Health Organization. At any given time, it afflicts around

350 million people worldwide and 18 million people in the U.S. Only a fraction of sufferers seek help, and of those, only a third respond to standard treatment, which is usually counseling and medication. Antidepressant drugs are often costly and can have serious side effects, driving many patients to search for less expensive, safer, more natural solutions. In a survey of more than 2,000 U.S. adults published in 2001, more than half of the respondents with depression said that they had turned to some kind of alternative treatment, such as yoga, herbal medicines or acupuncture.

Psychologists and clinicians have studied exercise as an alternative treatment for depression for at least 30 years. Blumenthal was one of the pioneers. In the 1980s, while researching how exercise helps patients with cardiovascular disease, he and his colleagues noticed an inadvertent secondary benefit: working out seemed to improve people’s moods and reduce symptoms of depression. They decided to investigate. One of their early studies, published in 1999, tracked the health of 156 elderly men and women diagnosed with depression as they exercised regularly or took antidepressants, or both. After 16 weeks, all three groups had improved equally, but relapse rates were lowest among patients who exercised.

In a follow-up study, published a decade later, they divided more than 200 adults with depression into four groups, each receiving a different intervention: supervised exercise classes, exercise at home, medication or placebo. They found that patients engaging in supervised exercise fared better than those working out at home and achieved nearly equivalent remission rates as those taking antidepressants: 45 versus 47 percent, respectively. By comparison, the home exercise group reached a 40 percent remission rate and the placebo group, 31 percent.

More recently, in a similar study in 2015, Swedish scientists assigned 946 pa-

FAST FACTS

LIFTING DEPRESSION AT THE GYM

- 1 A growing body of evidence shows that exercise is an effective treatment for mild to moderate depression.
- 2 Exercise strengthens our biochemical resilience to stress, encourages the growth of new brain cells, bolsters self-esteem and may even counterbalance an underlying genetic risk for mental illness.
- 3 Moreover, the inverse is true: physical inactivity increases the risk for depression.

Although no treatment for depression works for everyone, exercise has proved to be just as effective as medication and counseling in several meta-analyses.



tients with mild to moderate depression to one of three 12-week treatments: thrice-weekly sessions of yoga, aerobics or strength training; Internet-based cognitive-behavioral therapy; or standard counseling plus medication. Patients in all groups improved, but those engaging in exercise experienced the greatest benefits. Internet-based therapy came in as a close runner-up, but the typical treatment plan lagged behind both alternatives.

To date, numerous meta-analyses have kept score on the accumulating data. They do not all agree: a few have found no indication that exercise is helpful or have found that it offers only very small effects or greatly diminished benefits in the long term. But most have reached similar optimistic conclusions. A 2013 review by the nonprofit organization Cochrane, regarded as a leader in evidence-based medicine, concluded that exercise is just as effective a treatment for depression as medication and counseling.

A recent meta-analysis, published in 2016, echoes Cochrane's finding. A team of international researchers examined 25 of the most rigorous experiments and determined that exercise, especially moderate to vigorous aerobic exercise under professional supervision, is indeed a potent treatment for depression. When they adjusted their analysis to account for weak

studies—those most prone to some kind of experimental bias—they found an even stronger effect, suggesting that some previous meta-analyses may have underestimated exercise's benefits for mental health. The researchers further calculated that it would take at least 1,000 contradictory studies to negate the affirming evidence that has piled up so far. Yet another review computed that when exercise is used to treat depression, success rates increase by as much as 67 to 74 percent.

How Much Is Enough?

Some researchers have attempted to figure out what types of exercise and intensity levels are most effective as an antidepressant. In a frequently cited study from 2005, for example, Trivedi and his colleagues tracked the health of 80 adults with mild to moderate depression for three months as they exercised three to five times a week on a treadmill or stationary bicycle at low intensity (seven kilocalories per kilogram per week) or at a higher intensity, as recommended by public health authorities (17.5 kilocalories per kilogram per week). At the end of the three months, the adults who exercised at the higher intensity had lessened the severity of their depression by 47 percent, compared with only 30 percent for the low-intensity group and 29 percent

for a group who engaged in stretching rather than aerobic exercise.

On the basis of studies such as this one, some psychologists, clinicians and health authorities have gone as far as publishing specific recommendations. Trivedi prescribes three to five 45- to 60-minute sessions of aerobic exercise (walking, running, cycling, or using a treadmill, stationary bike or elliptical trainer) each week at an intensity of 50 to 85 percent maximum heart rate. "The ideal is probably at least 16 kilocalories per kilogram of body weight, which works out to 1,200 to 1,500 kilocalories each week for average body weight," Trivedi says. "If you can talk to your spouse on the phone, you're not working out at the right intensity."

Likewise Central Queensland University exercise psychologist Robert Stanton advises 30- to 40-minute sessions of aerobic exercise—walking, cross training or stationary cycling—three to four times a week at low to moderate intensity for at least nine weeks. And the National Institute for Health and Care Excellence advocates group-based physical activity programs for patients with mild to moderate depression, consisting of at least three 45-minute sessions a week for at least 10 weeks.

Other experts, however, think it may be too soon to get so specific. A 2013 re-



Group exercise offers the same physiological and psychological benefits as solo workouts plus social interaction, which can also ease depressive symptoms.

view paper, for instance, concluded that both cardiovascular and resistance exercise, either alone or in combination, are effective at treating depression but that there are not yet enough data to definitively favor one form of physical activity over another. “Which exercise has the best mood effects, and what intensity is best? Does it work better alone or combined with other treatments? We don’t know for certain yet,” says psychologist Michael Otto of Boston University, who has studied both the emotional and cognitive benefits of exercise. “We can make some general suggestions, but we still need more data to be confident about the specifics.”

Why Exercise Works

In the past decade scientists have uncovered numerous details about how exercise alters the brain, and the body as a whole, in ways that alleviate and protect

against depression. The second you start running, pedaling or lifting a dumbbell, your body’s chemistry begins to change. Exercise boosts your heart rate, sending blood, oxygen, hormones and neurochemicals surging through the body. In the moment, the body responds to exercise as a kind of stress—but it is ultimately beneficial. Some evidence suggests that habitual moderate exercise rewires the brain and immune system to better cope with physical and mental strain. The better the body becomes at dealing with stressors of all kinds, the lower the risk of a depressive episode. In fact, many researchers think of depression as a disorder of managing stress.

Exercise also seems to mimic some of the chemical effects of antidepressant medication. Based on increasing evidence, some scientists argue that certain cases of depression result from the impaired growth of both brain cells and the connections between them. Studies have documented the atrophy and loss of neurons in brain regions such as the amygdala, hippocampus and prefrontal cortex in patients with major depression. Antidepressants that increase levels of serotonin and other neurotransmitters might work by reinvigorating neural proliferation, a process that depends in part on a mole-

cule called brain-derived neurotrophic factor (BDNF). In studies with both animals and people, exercise enhances the production of BDNF.

In one 2001 study, for example, rats given an antidepressant and the opportunity to run produced higher levels of BDNF compared with animals that only ran or only received medication. Moreover, they were better at enduring a stressful experience, swimming for longer in an inescapable water tank before giving up—a test designed to approximate the onset of depression. In an analogous human study in 2016, Brazilian researchers divided 57 adults taking the antidepressant sertraline for moderate to severe depression into two groups: one attended four weekly sessions of aerobic activity for 28 days, and the other did not exercise. Symptoms abated similarly in both groups, but the exercise group improved on lower doses of antidepressants. The authors suspect that exercise enhanced the biochemical effects of the drugs. Similar studies have shown that simply recommending healthy lifestyle changes, such as establishing better sleep routines and getting more exercise, can dramatically boost the efficacy of antidepressants from a mere 10 percent remission rate with the drugs alone to a 60 percent remission rate.

And in a small but intriguing 2015 study, physician Helmuth Haslacher and his colleagues at the Medical University of Vienna in Austria compared the mental health and genomes of 55 elderly marathon runners and endurance bicyclists with those of 58 nonathletes. Among the nonathletes, they found a statistically significant correlation between the number of depressive symptoms these individuals experienced and a particular gene variant that interferes with normal BDNF production. Among the athletes, however, there was no such correlation. The researchers concluded that by stimulating BDNF production, long-term, vigorous aerobic exercise might actually counteract a genetic susceptibility to depression.

Neurobiology may also explain why, in addition to exercise countering depression, the inverse seems to be true: correlations in epidemiological surveys suggest

THE AUTHOR

FERRIS JABR is a contributing writer for *Scientific American* and a contributing editor for *Scientific American Mind*. He has also written for the *New York Times Magazine*, the *New Yorker* and *Outside*.

that physical inactivity, while sometimes the result of depression, may also be a major risk factor for subsequently developing it. In a 2014 study of more than 6,000 elderly U.K. citizens, the more time they spent watching television, the more likely they were to report symptoms of depression (although this was not true for other sedentary activities such as reading). Those who participated in some form of vigorous physical activity at least once a week experienced less depression. Likewise, a 2015 survey of nearly 5,000 Chinese college students found that the more time a student spent in front of a TV or computer screen, the more likely he or she was to have depressive symptoms. In contrast, the risk for depression dropped the more physically active a student was, regardless of age, gender or residential background. A meta-analysis of 24 studies, involving nearly 200,000 participants, reached the same conclusion: sedentary behavior was associated with an increased risk of depression. On average, active people are 45 percent less likely to be depressed than inactive people, according to the U.S. Office of Disease Prevention and Health Promotion.

The Feel-Good Factor

Beyond these physiological reasons, many social and psychological factors help to explain why working out can alleviate symptoms of depression. In comprehensive interviews, people who have struggled with the disorder say that exercise energizes them, gives them a sense of purpose and achievement, elevates their self-esteem and mood, regulates appetite and sleep cycles, and distracts them from negative thoughts. For those who exercise in a group, it can also provide a welcome opportunity for social interaction.

First, though, many people with depression must overcome a severe lack of motivation. “We need to educate people and give them tools to help monitor their progress,” Trivedi says. “We make patients log in and communicate with us. If we find out they have skipped a day, we work with them to solve the problem and make sure that by the end of week, they complete their regimen.” Jennifer Carter,

Looking for Motivation? Remember These TIPS

**10 minutes of exercise
is better than none.**

**Set yourself challenging
but realistic goals.**

**If you aren't exercising at all,
start by taking the stairs
instead of the elevator or
call a friend to schedule a
walk once or twice a week.**

**Identify what motivates you:
if you are competitive, join a
recreational sports league; if
you are a social butterfly, join
an exercise class; if you are
a nature buff, go on a hike.**

director of sport psychology at the Ohio State University Wexner Medical Center, has come up with a bevy of practical tips, among them: “Notice the facts,” she advises. “For example, there are 1,440 minutes in a day. Perhaps you can find 30 of those to exercise.” [For more of Carter's suggestions, see box above.]

Getting over that initial hurdle of low motivation seems to depend in particular on how much satisfaction and self-agency people experience while working out. “Enjoyment is fundamentally linked to how much people stick with exercise,” Otto says. “I want them to do what is most fun and entertaining, whatever that might be.” Research suggests that exercise as therapy succeeds when people choose the type and intensity. Most people prefer a moderate intensity, around or

just below the ventilatory threshold—the point at which breathing becomes noticeably labored. In 2011 Patrick Callaghan, head of health sciences at the University of Nottingham in England, and his colleagues asked 38 women with depression to exercise on treadmills in small groups three times a week, either at a prescribed intensity or one they personally selected. After a month, the women who chose how much to exert themselves had lower levels of depression and higher self-esteem compared with the other group.

Despite the mounting evidence that exercise can remedy some forms of depression, skepticism persists in academia and health care, Trivedi notes. “There is this general bias that exercise is not a bona fide treatment—it's just something you should do in addition to treatment, like trying to sleep and eat well,” he says. “Even though recognition of exercise as a treatment is increasing,” only some health insurance companies pay for gym time, he explains, and when they do, they often offer small temporary discounts. “I can prescribe a drug that costs \$200 and insurance will pay, but they won't give \$40 to open a gym membership.”

Patients will need to change their thinking as well. “It can be hard for patients to think of exercise as a form of treatment,” Otto comments. “We usually exercise to look good at the beach, to lose weight.” Most individuals do not understand the degree to which exercise can reshape their mood, too. “Even if you feel like pulling in and doing nothing, exercise pushes you out,” he adds. “Depression makes you feel like everything you're about to do is useless and pointless. That's exactly what exercise fights—you have to get up and go.” **M**

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THE MORALITY FACTOR

Overlooked in previous models of personality, moral character turns out to be key in predicting job performance and leadership potential

By Taya R. Cohen

ILLUSTRATION BY JONATHAN BARTLETT





What if you could ask a job applicant a few questions that would allow you to accurately predict whether he or she would be a good employee? Is this person likely to be absent frequently, falsify expense reports and claim credit for work done by other team members? Or, on the plus side, will he or she cheerfully volunteer for extra assignments, deal patiently with difficult clients, mentor junior associates and be a good leader?

The fact is, there is a reliable way to tell, but it is often neglected by employers and hiring managers: ask questions that elicit information about character. Too often employers focus narrowly on competence and prior experience. Yet evidence from recent psychological studies shows that people work harder and perform better at their jobs when they have high standing on three key character traits: honesty-humility, conscientiousness and guilt proneness.

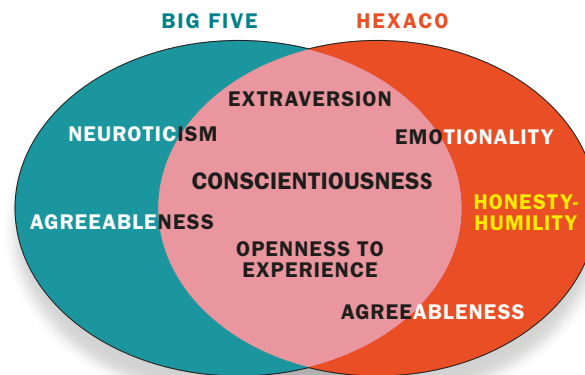
Honesty-humility and conscientiousness are two of the six broad dimensions of personality summarized by the HEXACO model of personality structure. (The other four are emotionality, extraversion, agreeableness and openness to experience.) This six-factor model has begun to replace the famous “big five” model of personality, as mounting evidence bears out its validity. Honesty-humility, a factor not included in the old model, captures the motivational aspect of moral character—the desire to do good and avoid wrongdoing. Conscientiousness captures the *willpower* element of moral character—the facility and determination to do the right thing.

Guilt proneness is not specifically described by the HEXACO model, although it is related. This trait captures thoughts and feelings that are a blend of honesty-humility and conscientiousness. Guilt proneness specifies the extent to which a person would feel bad if he or she did something wrong, even if no one

knew about it. It reflects a deep sense of responsibility for others, which helps to explain why recent studies from my team and others have found that a person’s guilt proneness is an excellent predictor of job performance and leadership skills. My colleagues and I are now working to create interview questions that can elicit information about this trait in ways that are useful to employers. As more and more companies lean on personality testing to help get a clear-

to experience, conscientiousness, extraversion, agreeableness and neuroticism. The model remains very popular, and assessments of the big five are still widely used by personality and organizational psychologists in research and practice. We now know, however, that this older model fails to capture critical elements of personality related to moral character and ethical behavior.

So how did the big five model go wrong? It emerged from empirical re-



The new HEXACO model of personality shares three factors with the older “big five” model. It uses a slightly updated definition of agreeableness, and it has revised neuroticism to cover emotionality. HEXACO adds a new, sixth factor: honesty-humility, a measure of moral character.

er picture of job applicants, our results are revealing the benefits of focusing on character in addition to competence.

From Five Factors to Six

Through the 1990s the big five model of personality dominated psychology, based on a wealth of studies going back to the 1960s. This model describes five groups of traits, sometimes abbreviated with the acronym “OCEAN”: openness

search that examined relations among a list of personality-related adjectives from the dictionary, such as “friendly,” “diligent” or “easygoing.” Research participants would rate themselves and other people on the extent to which each adjective described that person. The researchers then would examine the associations among the items through a statistical technique called factor analysis to determine the minimum number of different categories (factors) that were needed to reliably summarize the information. In this case, the adjectives clumped into five groups. This lexical approach to examining personality began in the 1930s but gained in popularity from the 1960s through the 1990s as statistical computing power improved.

FAST FACTS

CONSIDERING CHARACTER

- 1 Moral character is described by the honesty-humility personality dimension, a factor that had been overlooked in the famous “big five” model of personality.
- 2 Honesty-humility, along with conscientiousness and guilt proneness, predicts positive job performance and ethical leadership.
- 3 Behavior-based interview questions can be used to gauge people’s moral character.

Honesty-humility, conscientiousness and guilt proneness each predicted who was prone to workplace deviance and good behavior.

One major limitation of the lexical studies that led to the big five is that they were based on limited lists of words in only the English language. In 1997 psychologists Kibeom Lee and Michael C. Ashton, then graduate students at the University of Western Ontario, decided to conduct a lexical study at a university in Seoul examining about 400 common Korean adjectives that could describe a person. By using this long non-English language word set, they found that there were six, not five, groups of traits. Three of these groups were basically the same as three from the big five model: conscientiousness, extraversion and openness to experience.

Emotionality (which is similar to the big five's neuroticism) and agreeableness also emerged in the new six-factor model, but they differed somewhat from their big five counterparts (some adjectives that were part of neuroticism in the big five model were part of agreeableness in HEXACO, and some adjectives that had been part of agreeableness now belonged to emotionality). Most interesting, a new group of traits emerged in this study that was not well represented in the older model: honesty-humility. This new factor contained adjectives such as ethical, honest, modest, loyal, sly, deceitful, greedy, pretentious and pompous.

The results from this study in Seoul led Ashton and Lee to wonder whether their findings were related to something specific to the Korean language or whether the six broad categories of traits they found were, in fact, universal. Was it possible that all the prior English-language studies—decades of research—had missed the honesty-humility dimension? Keeping in mind that the earlier studies all relied on relatively small lists of words because of historical limitations in computing power, Ashton and Lee ran more studies in English and other languages. They also looked back at old English-language data collected by other researchers in the past that could now be analyzed with more

powerful computers. The six-factor HEXACO model emerged every time.

By 2007 the HEXACO model of personality structure had been confirmed in a dozen different languages. No more than six categories of traits have ever been reliably obtained in lexical studies in any language that has been researched so far. Today, 20 years since their initial study began, the “big six” model that Ashton and Lee termed HEXACO continues to be supported, with new evidence published regularly in top-tier psychology journals.

Predicting Job Performance

In the years since honesty-humility was revealed as a distinct element of personality, psychological studies have

linked it to a variety of traits and behaviors. One of the most robust lines of inquiry has to do with behavior on the job—specifically, workplace deviance and organizational citizenship. Workplace deviance such as theft, sabotage and withdrawal by employees costs organizations billions of dollars a year and has profoundly harmful effects on employees in organizations where such abuses occur. On the flip side are helpful work behaviors—known as organizational citizenship behaviors, or OCBs for short. Examples include volunteering to mentor co-workers, switching schedules or working extra hours to accommodate others' needs, coming in early or working late to ensure projects get done,



Guilt vs. Shame

After realizing you have received too much change at a store, you decide to keep it because the salesclerk doesn't notice. How likely are you to feel uncomfortable about keeping the money?

Researchers use such questions to assess guilt proneness, a personality trait that encompasses aspects of honesty-humility and conscientiousness.

With colleagues at the University of North Carolina at Chapel Hill in 2011, I developed the Guilt and Shame Proneness scale—GASP—a now widely used tool to measure people's propensity to experience guilt and shame in response to wrongdoing. Studies using the scale have shown that guilt proneness predicts a variety of positive behaviors inside and outside the workplace, including being an honest and trustworthy negotiator, being a responsible and valued team member, and being a good leader and star performer at work.

Guilt proneness—the personality trait—taps into psychologically healthy guilt, not the unhealthy, debilitating kinds of ruminations that might lead to anxiety, depression or mental illness. The latter types of feelings, I would argue, are not truly guilt but rather shame. Shame is feeling bad about oneself, whereas guilt is feeling bad about one's behavior. The former leads people to hide or lash out at others. But the latter leads to positive behaviors that help rather than harm others, such as apologizing and trying not to err again, and that is why psychologists recognize guilt as the quintessential moral emotion.

To find out your level of guilt proneness, take a quiz at www.guiltproneness.org.

—T.R.C.

MBA students who scored higher on guilt proneness were rated as more effective leaders by their former supervisors, peers and clients.

and lending a compassionate ear to colleagues having problems.

To examine the relation between character and job performance, my colleagues and I conducted a three-month study of approximately 1,500 employees in hundreds of different organizations and different jobs across the U.S. In 2011 and 2012 we surveyed employees weekly about their workplace deviance (anything from stealing pens to faking illness) and organizational citizenship. Prior to finishing the weekly surveys, they completed an initial questionnaire about their personality and the organization where they worked. We also surveyed their co-workers about the employees' job performance over the course of one month.

The results, which we published in 2014, revealed that honesty-humility, conscientiousness and guilt proneness each predicted workplace deviance and organizational citizenship. Both self-reports and co-worker reports revealed many more misdeeds for those low in these traits [see graphs at right]. The fact that co-worker reports aligned with the self-reports rules out the possibility that some people are simply more willing than others to admit to wrongdoing.

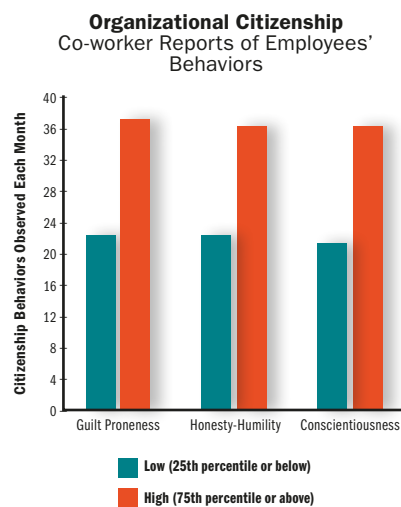
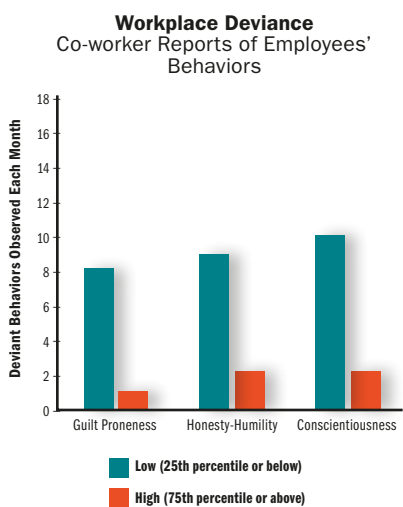
The relations between organizational citizenship and these character traits were less clear but still suggestive of more helpful behavior among those high in honesty-humility, conscientiousness and guilt proneness. For example, employees with relatively low guilt proneness scores reported that they committed an average of 14 OCBs per week, whereas those with relatively high guilt proneness scores reported an average of 17. We found no significant differences in self-reported citi-

zenship behavior between those low and high in honesty-humility or conscientiousness, but their co-workers did see significant differences. For instance, people low in guilt proneness were seen committing an average of 22 citizenship acts in a month, whereas those high in guilt proneness had an average of 37. This pattern was the same for honesty-humility and conscientiousness.

We do not know why stronger pat-

scious of their own altruistic behaviors. Similarly, it is possible that those who have low levels of these traits hold an overly generous view of their own positive behavior.

Subsequent studies by my team and others have borne out the importance of these character traits for job performance. For example, a 2016 study my colleagues and I conducted of law-enforcement job applicants in Colorado found



Employees high in guilt proneness, honesty-humility and conscientiousness report committing far fewer acts of deviance and more citizenship behaviors than those low on these traits. Reports by their co-workers, shown above, confirm that the self-reports are accurate.

terns emerged in the co-worker reports of good deeds than in the self-reports. One possibility is that employees who score high in honesty-humility, conscientiousness and guilt proneness are less aware of the helpful acts that others spot. That is, their humility and task focus are so strong that they are not fully con-

that nearly one third of those with relatively low guilt proneness scores (the bottom quartile of the sample) had been fired from a previous job. Moreover, many of the job applicants with very low guilt proneness scores (the bottom 10 percent) were deemed unsuitable for hire by a psychologist retained by the law-enforcement agencies to assess job candidates.

THE AUTHOR

TAYA R. COHEN is an associate professor of organizational behavior and theory at the Tepper School of Business at Carnegie Mellon University and holds the Carnegie Bosch Junior Faculty Chair. In her current research she is investigating how to identify morally exceptional future business leaders.

Effective Leadership

Our study of workplace deviance and citizenship provides clear evidence of the damage that employees with low levels of honesty-humility, conscientiousness and

SOURCE: TAYA R. COHEN

guilt proneness do to their colleagues and the organizations where they work. But are they also worse leaders?

Although research on the HEXACO traits and leadership is limited, there are dozens of studies on the big five personality traits that point to the importance of conscientiousness for leadership emergence and effectiveness. The dependability and achievement focus of individuals high in this trait help them rise to the top and be effective in positions of power. Strong evidence for this relation comes from a meta-analysis by Timothy Judge, then at the University of Florida, and his colleagues. His team conducted a quantitative and qualitative review of more than 70 studies of the big five traits and leadership. Among all the big five traits, conscientiousness was second only to extraversion in its impact on leadership. Extraversion is characterized by high levels of dominance and sociability, so its strong relation to leadership is to be expected. But the effect of conscientiousness was almost the same magnitude.

As for honesty-humility, high levels of this trait have been shown to predict ethical leadership. In 2012 Reinout de Vries of the VU University Amsterdam found that business leaders from a variety of small and large companies who had higher levels of honesty-humility were rated as more ethical by their subordinates. Consistent with the idea that it is the combination of high honesty-humility and conscientiousness that makes for a particularly ethical person, conscientiousness was also found to correlate with ethical leadership.

Guilt proneness has been found to predict leader effectiveness. Among the studies showing this is one published in 2012 by Rebecca Schaumberg, now at New York University, and Francis Flynn of Stanford University. The researchers surveyed supervisors, colleagues and direct reports of 139 students entering a master of business administration (MBA) program at an elite U.S. business school. The surveys contained questions about various facets of leader effectiveness: the ability to achieve results, manage others, manage oneself and communicate effectively. The students themselves were sur-

Can a Dishonest Person Change?

Honesty-humility, like all the HEXACO personality dimensions, can be thought of as a broad habit—or the way someone behaves most of the time. Yet unlike, say, extraversion, studies show that honesty-humility scores tend to increase substantially across our life span. In other words, a person who is dishonest as a teenager is not doomed to be a dishonest adult. For most of us, honesty-humility and guilt proneness increase dramatically from about the time we enter adult life, around 20 years old, until we are in our 60s.

Another way to conceptualize change in personality is to consider “rank order” stability—that is, the extent to which a person who is relatively high (or low) on a given trait will continue to rank relatively high (or low) over time compared with peers. Rank-order change from young adulthood to older age is, in general, quite minimal. This means that a young person who is more honest and conscientious than his or her classmates will likely continue to be relatively more honest and conscientious than same-aged adults as he or she grows older.

This stability is not predestined—people can and occasionally do change their relative standing. But dispositions and habits emerge very early in life and are based in part on genetic influences. The nature-nurture debate continues to be a lively one, but the emerging consensus from twin studies is that approximately 60 percent of the variation in personality differences can be attributed to genetic influences. This appears to be just as true for moral character traits as it is for other characteristics. —T.R.C.



veyed about their guilt proneness and sense of responsibility for others, as well as the big five traits. Their intelligence was examined by collecting their scores on the Graduate Management Admission Test (GMAT).

MBA students who tested as having higher levels of guilt proneness reported a greater sense of responsibility for others and were rated as more effective leaders by their former supervisors, direct reports, peers and clients. Positive relations with leadership effectiveness also emerged for conscientiousness and extraversion, but these correlations were weaker.

Although plenty of research indicates intelligence is important for many aspects of job performance, Schaumberg and Flynn found no relation between leader effectiveness and GMAT scores. GMAT scores were also unrelated to guilt proneness, conscientiousness and sense of responsibility for others (and GMAT scores

were negatively related to extraversion), suggesting that selecting employees based exclusively on standardized test scores or other indicators of intelligence would be a mistake. Instead the results of this study suggest that organizations seeking effective leaders should consider guilt proneness in their hiring and promotion decisions. Employees who anticipate that they would feel bad about their behavior after doing something wrong are better able to get along and get results.

In thinking about these findings, it is important to keep in mind that not all organizations desire an ethical and responsible leader, though when asked, most will say that they do. There are indeed certain tasks and roles in organizations—such as cost-cutting and downsizing—that require a cold, self-focused approach. For those types of jobs, a Machiavellian narcissist would likely do just fine—too much empathy and concern for

How Ethical Are You?

The psychologists who developed the six-factor HEXACO personality model, Kibeom Lee and Michael C. Ashton, have made their personality test available at <http://hexaco.org/hexaco-online>. There you can size up your own levels of honesty-humility, along with emotionality, extraversion, agreeableness, conscientiousness and openness to experience.

other people would be a liability. That said, such tasks and roles are relatively rare as compared with ones that involve getting along and getting ahead by working with and leading others. Insensitive and unethical behavior may, in some circumstances, bring positive business results in the short term, but there is a real risk of long-term damage for the organization and society if individuals with low levels of moral character are appointed to high-level leadership positions.

One final note: Organizations must be cautious in appointing leaders who say they would not feel uncomfortable about a decision that harms other people. Sometimes leadership requires such decisions, but a person with this level of indifference is likely to choose the selfish path when deciding between options that lead to personal advancement and those that benefit the organization at large.

Character Assessment on the Job

Psychologists have developed and validated self-report and peer-report

questionnaires for measuring honesty-humility, conscientiousness and guilt proneness. These assessments do a very good job of measuring character in anonymous research settings, but how do they fare in high-stakes settings, such as hiring?

As you might imagine, character assessment becomes more difficult when individuals are highly motivated to make a positive impression. This is not to say that personality tests do not have value in such settings—indeed, they are widely used by organizations, and their validity has been substantiated with solid evidence from psychologists Robert Hogan and Joyce Hogan of Hogan Assessment Systems, as well as many others over the past several decades.

Still, the century-old argument that “faking” invalidates personality assessment has not been entirely debunked, and the debate continues. Self-reports and peer reports do have value in high-stakes settings, but they are not infallible, and their predictive power is far from 100 percent. Therefore, it is critical that organizations complement personality testing with other methods.

Behavior-based interview questions are one option. In my current research with Yeonjeong Kim of Carnegie Mellon University and Abigail Panter of the University of North Carolina at Chapel Hill, we are exploring whether valid information about a person’s character can be gleaned from such questions. Here is one that seems to work well:

“Please describe a time when you made a mistake at work. How did you feel when this occurred? What did you do? What, if anything, did you learn from this experience?”

When people respond to this set of questions, they often communicate information about their guilt proneness, honesty-humility and conscientiousness, which in turn can be used to predict ethical decision making and behavior. Our research on detecting character via interview questions is still in its early stages, but our results thus far are promising. Some studies suggest that it may be possible to train people to correctly identify personality traits from such open-ended interview questions. For example, a 2016 study by psychologists Deborah Powell of the University of Guelph and Joshua Bourdage of the University of Calgary found that undergraduate business students could be trained to more accurately identify key personality traits from videos of interviews.

Knowing that high levels of guilt proneness, honesty-humility and conscientiousness are hallmarks of an ethical employee gives us strong clues as to what we should look for when making hiring decisions and promoting people to leadership positions. When evaluating a job candidate or future leader, ask yourself:

Would this person feel bad about committing a transgression or making a mistake even if no one knew about what he or she did? Does he or she have a strong sense of responsibility for others? Would this person feel bad about letting others down? Is this person truthful, humble and fair? Is he or she hard-working, careful and thorough when completing tasks?

If the answer to these questions is no, then the individual is unlikely to be an ethical worker and will probably be an ineffective and disreputable leader. Conversely, if the answer is yes, you can bet that he or she will be a good colleague and star performer in the organization—a person who will exhibit decency and integrity when called upon to lead. **M**

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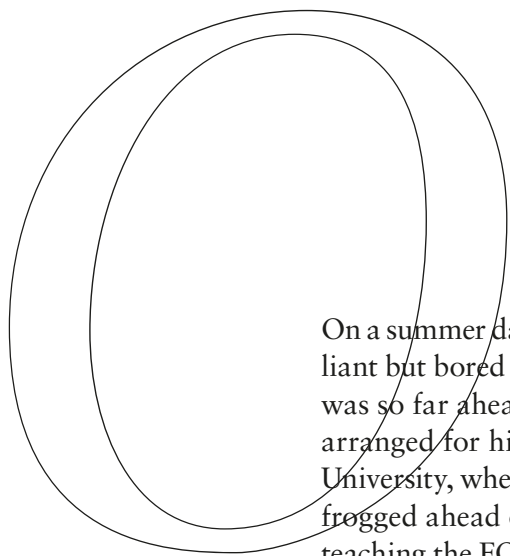


A decades-long study of exceptionally gifted children reveals what it takes to hone the world's sharpest minds

By Tom Clynes

ILLUSTRATION BY SONIA ROY

This article was originally published in the September 8, 2016, issue of *Nature* with the title "How to Raise a Genius: Lessons from a 45-Year Study of Super-Smart Children." It is reprinted with permission from *Nature*, which, like *Scientific American Mind*, is part of Springer Nature.



On a summer day in 1968, psychology professor Julian Stanley met a brilliant but bored 12-year-old named Joseph Bates. The Baltimore student was so far ahead of his classmates in mathematics that his parents had arranged for him to take a computer science course at Johns Hopkins University, where Stanley taught. Even that wasn't enough. Having leapfrogged ahead of the adults in the class, the child kept himself busy by teaching the FORTRAN programming language to graduate students.

Unsure of what to do with Bates, his computer instructor introduced him to Stanley, a researcher well known for his work in psychometrics—the study of cognitive performance. To discover more about the young prodigy's talent, Stanley gave Bates a battery of tests that included the SAT college admissions exam.

Bates's score was well above the threshold for admission to Johns Hopkins, which prompted Stanley to search for a local high school that would let the child take advanced mathematics and science classes. When that plan failed, Stanley convinced a dean at Johns Hopkins to let Bates, then 13, enroll as an undergraduate.

Stanley would affectionately refer to Bates as “student zero” of his Study of Mathematically Precocious Youth (SMPY), which would transform how gifted children are identified and supported by the U.S. education system. As the longest-running longitudinal survey of intellectually talented children, SMPY has for 45 years tracked the ca-

reers and accomplishments of some 5,000 individuals, many of whom have gone on to become high-achieving scientists. The study's ever growing data set has generated more than 400 papers and several books and provided key insights into how to spot and develop talent in science, technology, engineering, mathematics (STEM), and beyond.

“What Julian wanted to know was, How do you find the kids with the highest potential for excellence in what we now call STEM, and how do you boost the chance that they'll reach that potential?” says Camilla Benbow, a protégé of Stanley's who is now dean of education and human development at Vanderbilt University. But Stanley was not interested in just studying bright children; he wanted to nurture their intellect and enhance the odds that they would change the world. His motto, he told his graduate students, was “no more dry bones methodology.”

With the first SMPY recruits now at the peak of their careers, what has be-

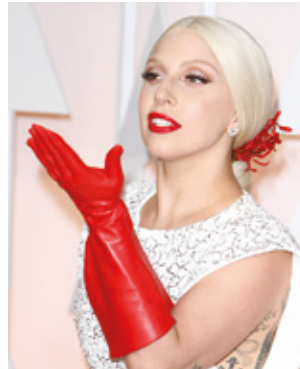
come clear is how much the precociously gifted outweigh the rest of society in their influence. Many of the innovators who are advancing science, technology and culture are those whose unique cognitive abilities were identified and supported in their early years through enrichment programs such as the Johns Hopkins Center for Talented Youth—which Stanley began in the 1980s as an adjunct to SMPY. At the start, both the study and the center were open to young adolescents who scored in the top 1 percent on university entrance exams. Pioneering mathematicians Terence Tao and Lenhard Ng were 1 percenters, as were Facebook's Mark Zuckerberg, Google co-founder Sergey Brin and musician Stefani Germanotta (Lady Gaga), who all passed through the Hopkins center.

“Whether we like it or not, these people really do control our society,” says Jonathan Wai, a psychologist at the Duke Talent Identification Program, which collaborates with the Hopkins center. Wai combined data from 11 prospective and retrospective longitudinal studies, including SMPY, to demonstrate the correlation between early cognitive ability and adult achievement. “The kids who test in the top 1 percent tend to become our eminent scientists and academics, our Fortune 500 CEOs, and federal judges, senators and billionaires,” he says.

FAST FACTS

HOW TO EDUCATE BRILLIANT KIDS

- 1 The Study of Mathematically Precocious Youth (SMPY) has been tracking outcomes of intellectually talented kids for 45 years, yielding more than 400 papers.
- 2 SMPY data strongly support grade skipping and other forms of acceleration.
- 3 Spatial ability is especially conducive to earning patents and securing advanced degrees.
- 4 While many Middle Eastern and East Asian countries have programs to identify and develop the talents of gifted kids, the U.S. and Europe tend to emphasize shoring up low achievers.



Among the alumni of the Johns Hopkins Center for Talented Youth are (left to right) Facebook co-founder and CEO Mark Zuckerberg, Google co-founder Sergey Brin, musical star Stefani Germanotta (aka Lady Gaga) and prizewinning mathematician Terence Tao. They were admitted after scoring in the top 1 percent on college admission tests at a precocious age.

Such results contradict long-established ideas suggesting that expert performance is built mainly through practice—that anyone can get to the top with enough focused effort of the right kind. SMPY, in contrast, suggests that early cognitive ability has more effect on achievement than either deliberate practice or environmental factors such as socioeconomic status. The research emphasizes the importance of nurturing precocious children, at a time when the prevailing focus in the U.S. and other countries is on improving the performance of struggling students. At the same time, the work to identify and support academically talented students has raised troubling questions about the risks of labeling children and the shortfalls of talent searches and standardized tests as a means of identifying high-potential students, especially in poor and rural districts.

“With so much emphasis on predicting who will rise to the top, we run the risk of selling short the many kids who are missed by these tests,” says Dona Matthews, a developmental psychologist in Toronto, who co-founded the Center for Gifted Studies and Education at Hunter College. “For those children who are tested, it does them no favors to call them ‘gifted’ or ‘ungifted.’

Either way, it can really undermine a child’s motivation to learn.”

A Study Begins

On a muggy August day, Benbow and her husband, psychologist David Lubinski, describe the origins of SMPY as they walk across the quadrangle at Vanderbilt. Benbow was a graduate student at Johns Hopkins when she met Stanley in a class he taught in 1976. Ben-

bow and Lubinski, who have co-directed the study since Stanley’s retirement, brought it to Vanderbilt in 1998. “In a sense, that brought Julian’s research full circle because this is where he started his career as a professor,” Benbow says as she nears the university’s psychology laboratory, the first U.S. building dedicated to the field, dating to 1915.

Stanley’s interest in developing scientific talent had been piqued by one of the most famous longitudinal studies in psychology, Lewis Terman’s Genetic Studies of Genius. Beginning in 1921, Terman selected teenage subjects on the basis of high IQ scores, then tracked and encouraged their careers. But to Terman’s chagrin, his cohort produced only a few esteemed scientists. Among those rejected, because his IQ of 129 was too low to make the cut, was William Shockley, the Nobel Prize-winning co-inventor of the transistor. Physicist Luis Alvarez, another Nobel winner, was also rejected.

Stanley suspected that Terman would not have missed Shockley and Alvarez if he had had a reliable way to test them specifically on quantitative reasoning ability. So Stanley decided to try the Scholastic Aptitude Test (now simply the SAT). Although the test is intended for older students, Stanley hy-

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DAVID RAMOS Getty Images (Zuckerberg); KIM KULISH Getty Images (Brin); ADRIANA M. BARRAZA age Fotostock (Lady Gaga); STEVE JENNINGS Getty Images (Tao)

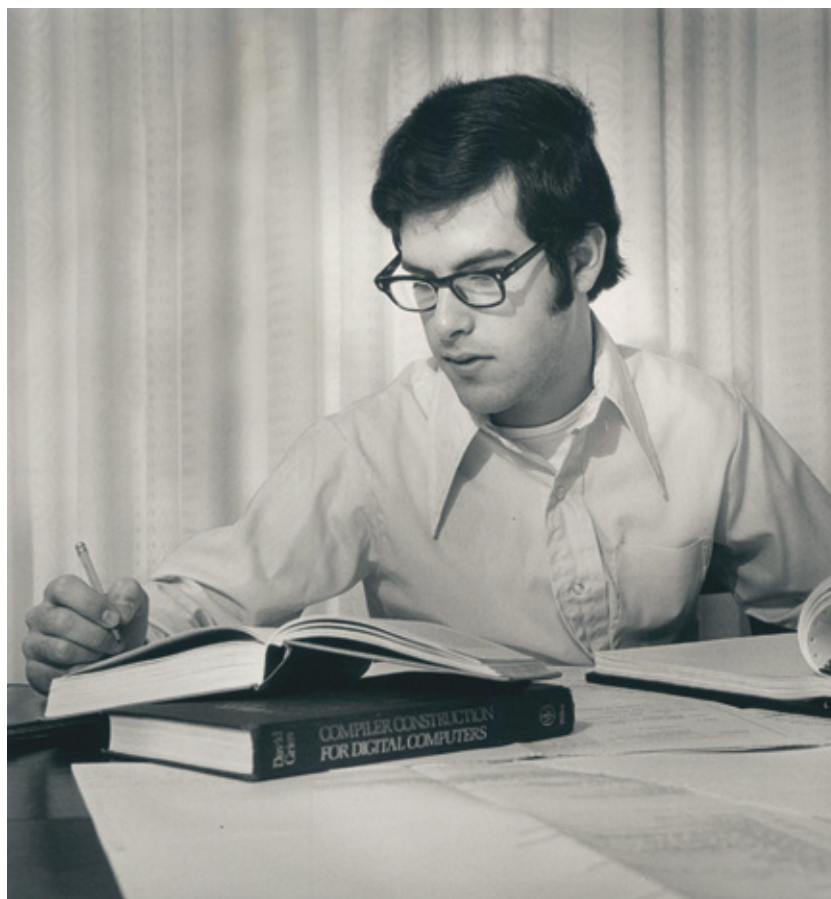
pothesized that it would be well suited to measuring the analytical reasoning abilities of elite younger students.

In March 1972 Stanley rounded up 450 bright 12- to 14-year-olds from the Baltimore area and gave them the mathematics part of the SAT. It was the first standardized academic “talent search.” (Later, researchers included the verbal part and other assessments.)

“The first big surprise was how many adolescents could figure out math problems that they hadn’t encountered in their course work,” says developmental psychologist Daniel Keating, then a Ph.D. student at Johns Hopkins. “The second surprise was how many of these young kids scored well above the admissions cutoff for many elite universities.”

Stanley had not envisioned SMPY as a multidecade longitudinal study. But after the first follow-up survey, five years later, Benbow proposed extending the study to track subjects through their lives, adding cohorts and including assessments of interests, preferences, and occupational and other life accomplishments. The study’s first four cohorts range from the top 3 percent to the top 0.01 percent in their SAT scores. The SMPY team added a fifth cohort of the leading mathematics and science graduate students in 1992 to test the generalizability of the talent-search model for identifying scientific potential.

“I don’t know of any other study in the world that has given us such a comprehensive look at exactly how and why STEM talent develops,” says Christoph Perleth, a psychologist at the University of Rostock in Germany who studies intelligence and talent development.



Computer scientist Joseph Bates became “student zero” at age 12 in the Study of Mathematically Precocious Youth. Shown here about a year before earning a master’s degree at 17, he went on to become a pioneer in artificial intelligence.

The Predictive Power of Spatial Skills

As the data flowed in, it quickly became apparent that a one-size-fits-all approach to gifted education, and education in general, was inadequate.

“SMPY gave us the first large-sample basis for the field to move away from general intelligence toward assessments

of specific cognitive abilities, interests and other factors,” says Rena Subotnik, who directs the Center for Gifted Education Policy at the American Psychological Association in Washington, D.C.

In 1976 Stanley started to test his second cohort (a sample of 563 13-year-olds who scored in the top 0.5 percent on the SAT) on spatial ability—the capacity to understand and remember spatial relations between objects. Tests for spatial ability might include matching objects that are seen from different perspectives, determining which cross section will result when an object is cut in certain ways, or estimating water levels on tilted bottles of various shapes. Stan-

THE AUTHOR

TOM CLYNES is an author and photojournalist whose work has appeared in *National Geographic*, *Nature*, the *New York Times* and many other publications. His most recent book is *The Boy Who Played with Fusion: Extreme Science, Extreme Parenting, and How to Make a Star* (Houghton Mifflin Harcourt, 2015).

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ley was curious about whether spatial ability might better predict educational and occupational outcomes than could measures of quantitative and verbal reasoning on their own.

Follow-up surveys—at ages 18, 23, 33 and 48—backed up his hunch. A 2013 analysis found a correlation between the number of patents and peer-reviewed publications that people had produced and their earlier scores on SATs and spatial-ability tests. The SAT tests jointly accounted for about 11 percent of the variance; spatial ability accounted for an additional 7.6 percent.

The findings, which dovetail with those of other recent studies, suggest that spatial ability plays a major part in creativity and technical innovation. “I think it may be the largest known untapped source of human potential,” says Lubinski, who adds that students who are only marginally impressive in mathematics or verbal ability but high in spatial ability often make exceptional engineers, architects and surgeons. “And yet no admissions directors I know of are looking at this, and it’s generally overlooked in school-based assessments.”

Although studies such as SMPY have given educators the ability to identify and support gifted youngsters, worldwide interest in this population is uneven. In the Middle East and East Asia, high-performing STEM students have received significant attention over the past decade. South Korea, Hong Kong and Singapore screen children for giftedness and steer high performers into innovative programs. In 2010 China launched a 10-year National Talent Development Plan to support and guide top students into science, technology and other high-demand fields.

In Europe and the U.S., support for research and educational programs for gifted children has ebbed, as the focus has moved more toward inclusion. England, for example, decided in 2010 to scrap the National Academy for Gifted and Talented Youth and redirected

funds toward an effort to get more poor students into leading universities.

Lessons from the Fast Track

When Stanley began his work, the choices for bright children in the U.S. were limited, so he sought out environments in which early talent could blossom. “It was clear to Julian that it’s not enough to identify potential; it has to be developed in appropriate ways if you’re going to keep that flame well lit,” says Linda Brody, who studied with Stanley and now runs a program at Johns Hopkins focused on counseling profoundly gifted children.

At first, the efforts were on a case-by-case basis. Parents of other bright children began to approach Stanley after hearing about his work with Bates, who thrived after entering university. By 17, he had earned bachelor’s and master’s degrees in computer science and was pursuing a doctorate at Cornell University. Later, as a professor at Carnegie Mellon University, he would become a pioneer in artificial intelligence.

“I was shy, and the social pressures of high school wouldn’t have made it a good fit for me,” says Bates, now 60. “But at college, with the other science and math nerds, I fit right in, even though I was much younger. I could grow up on the social side at my own rate and also on the intellectual side because the faster pace kept me interested in the content.”

The SMPY data supported the idea of accelerating fast learners by allowing them to skip school grades. In a comparison of children who bypassed a grade with a control group of similarly smart children who did not, the grade skippers were 60 percent more likely to earn doctorates or patents and more than twice as likely to get a Ph.D. in a STEM field. Acceleration is common in SMPY’s elite one-in-10,000 cohort, whose intellectual diversity and rapid pace of learning make them among the most challenging

to educate. Advancing these students costs little or nothing and, in some cases, may save schools money, Lubinski says. “These kids often don’t need anything innovative or novel,” he says. “They just need earlier access to what’s already available to older kids.”

Many educators and parents continue to believe that acceleration is bad for

As the data flowed in, it became apparent that a one-size-fits-all approach to gifted education, and education in general, was inadequate.

children—that it will hurt them socially, push them out of childhood or create knowledge gaps. But education researchers generally agree that acceleration benefits the vast majority of gifted children socially and emotionally, as well as academically and professionally.

Skipping grades is not the only option. SMPY researchers say that even modest interventions—for example, access to challenging material such as college-level Advanced Placement courses—have a demonstrable effect. Among students with high ability, those who were given a richer density of advanced precollegiate educational opportunities in STEM went on to publish more academic papers, earn more patents and pursue higher-level careers than their

equally smart peers who did not have these opportunities.

Despite SMPY's many insights, researchers still have an incomplete picture of giftedness and achievement. "We don't know why, even at the high end, some people will do well and others won't," says Douglas Detterman, a psychologist who studies cognitive ability at Case Western Reserve University. "Intelligence won't account for all the differences between people; motivation, personality factors, how hard you work and other things are important."

Some insights have come from German studies that have a methodology similar to SMPY's. The Munich Longitudinal Study of Giftedness, which started tracking 26,000 gifted students in the mid-1980s, found that cognitive

factors were the most predictive but that some personal traits—such as motivation, curiosity and ability to cope with stress—had a limited influence on performance. Environmental factors, such as family, school and peers, also had an impact.

The data from such intellectual-talent searches also contribute to knowledge of how people develop expertise in subjects. Some researchers and writers, notably psychologist K. Anders Ericsson of Florida State University and author Malcolm Gladwell, have popularized the idea of an ability threshold. This holds that for individuals beyond a certain IQ barrier (120 is often cited), concentrated practice time is much more important than additional intellectual abilities in acquiring expertise.

But data from SMPY and from the Duke talent program dispute that hypothesis. A study published in 2016 compared the outcomes of students in the top 1 percent of childhood intellectual ability with those in the top 0.01 percent. Whereas the first group gained advanced degrees at about 25 times the rate of the general population, the more elite students earned Ph.D.s at about 50 times the base rate.

But some of the work is controversial. In North America and Europe, some child development experts lament that much of the research on talent development is driven by the urge to predict who will rise to the top, and educators have expressed considerable unease about the concept of identifying and labeling a group of pupils as gifted or talented.

"A high test score tells you only that a person has high ability and is a good match for that particular test at that point in time," Matthews says. "A low test score tells you practically nothing," she says,

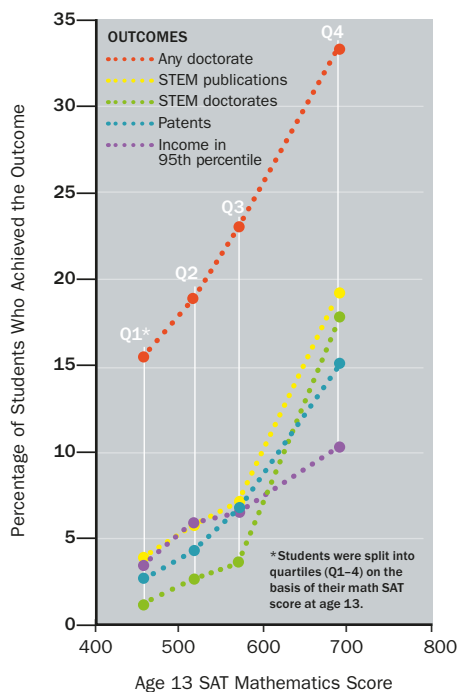
There is an enduring misperception among educators that gifted kids are bright enough to succeed on their own and that we should focus more on low-performing students.

because many factors can depress students' performance, including their cultural backgrounds and how comfortable they are with taking high-stakes tests. Matthews contends that when children who are near the high and low extremes of early achievement sense they are being assessed in terms of future success, it can damage their motivation to learn and can contribute to what Stanford University psychologist Carol S. Dweck calls a fixed mindset. It is far better, Dweck says, to encourage a growth mindset, in which children believe that brains and talent are merely a starting point and that abilities can be developed through hard work and continued intellectual risk-taking.

"Students focus on improvement instead of worrying about how smart they are and hungering for approval," Dweck explains. "They work hard to learn more and get smarter." Research by Dweck and her colleagues shows that students who learn with this mindset show greater motivation at school, get better marks and have higher test scores. Benbow agrees that standardized tests should not

TOP OF THE CHARTS

Long-term studies of gifted students—those who scored in the top 1 percent as young adolescents on the math section of the SAT—reveal that the highest scorers (*upper quartile*) went on to outperform the rest by several measures.





Summer enrichment: Fifth and sixth graders collaborate on a health research project at a Duke Talent Identification Program at Southwestern University in Texas (left). Middle and high school students count bacteria in a petri dish for a genetics course at the Johns Hopkins Center for Talented Youth (right).

be used to limit students' options but rather to develop learning and teaching strategies appropriate to children's abilities, which allow students at every level to reach their potential.

This year Benbow and Lubinski plan to launch a midlife survey of the profoundly gifted cohort (the one in 10,000), with an emphasis on career achievements and life satisfaction, and to resurvey their 1992 sample of graduate students at leading U.S. universities. The forthcoming studies may further erode the enduring misperception that gifted children are bright enough to succeed on their own, without much help.

"The education community is still resistant to this message," says David Geary, a cognitive developmental psychologist at the University of Missouri who specializes in mathematical learning. "There's a general belief that kids who have advantages, cognitive or otherwise, shouldn't be given extra encouragement, that we should focus more on lower-performing kids."

Although gifted-education special-

ists herald the expansion of talent-development options in the U.S., the benefits have mostly been limited so far to students who are at the top of both the talent and socioeconomic curves. "We know how to identify these kids, and we know how to help them," Lubinski observes. "And yet we're missing a lot of the smartest kids in the country."

As Lubinski and Benbow walk through the quadrangle, the clock strikes noon, releasing packs of enthusiastic adolescents racing toward the dining hall. Many are participants in the Vanderbilt Programs for Talented Youth, summer enrichment courses in which gifted students spend three weeks gorging them-

selves on a year's worth of mathematics, science or literature. Others are participants in Vanderbilt's sports camps.

"They're just developing different talents," says Lubinski, a former high school and college wrestler. "But our society has been much more encouraging of athletic talents than we are of intellectual talents." And yet these gifted students, the "mathletes" of the world, can shape the future. "When you look at the issues facing society now—whether it's health care, climate change, terrorism, energy—these are the kids who have the most potential to solve these problems," Lubinski says. "These are the kids we'd do well to bet on." **M**

MORE TO EXPLORE

- **Creativity and Technical Innovation: Spatial Ability's Unique Role.** Harrison J. Kell et al. in *Psychological Science*, Vol. 24, No. 9, pages 1831–1836; September 2013.
- **Beyond Intelligence: Secrets for Raising Happily Productive Kids.** Dona Matthews and Joanne Foster. Anansi, 2014.
- **Experts Are Born, Then Made: Combining Prospective and Retrospective Longitudinal Data Shows That Cognitive Ability Matters.** Jonathan Wai in *Intelligence*, Vol. 45, pages 74–80; July–August 2014.
- **Life Paths and Accomplishments of Mathematically Precocious Males and Females Four Decades Later.** David Lubinski et al. in *Psychological Science*, Vol. 25, No. 12, pages 2217–2232; December 2014.
- **From Terman to Today: A Century of Findings on Intellectual Precocity.** David Lubinski in *Review of Educational Research*. Published online October 27, 2016.

From Our Archives

- **The Secret to Raising Smart Kids.** Carol S. Dweck; December 2007/January 2008.
- **Coaching the Gifted Child.** Christian Fischer; August/September 2008.



THE CURRENCY OF

Rethinking the “pleasure molecule” could help scientists better understand addiction, Parkinson’s disease and motivation

BY MAIA SZALAVITZ

ILLUSTRATION BY GUYCO

W

hen Stephanie,* a 34-year-old middle manager from the Midwest, began to overeat, it was not typical behavior for her. She had never before had trouble with her weight. But in 2009 she started to feel an overwhelming hunger—particularly for sugar—and was soon rapidly piling on pounds.

Then just as abruptly, Stephanie developed an obsession with gambling. She would play games of chance online. “I’d never bought a lottery ticket in my life,” she recalls. Yet she began to do so compulsively: “I would go from gas station to gas station. I had places that in my mind I thought were better places to win.”

Stephanie did not realize it until years later, but her behaviors could all be explained as side effects from a medication called Mirapex (pramipexole). Her doctor had prescribed it to

treat Parkinson’s disease, with which she had been diagnosed at the unusually young age of 29. Parkinson’s is a neurodegenerative condition that causes tremor and movement difficulties. Although much about it remains mysterious, scientists know that the disease gradually destroys brain cells that produce the neurotransmitter dopamine. Mirapex acts, in a sense, as an artificial version of this molecule, activating the same receptors in the brain, which can help explain Stephanie’s problems.

*Not her real name.



Although few of us spend time contemplating the molecular messengers at work in our brain, we owe a tremendous amount to them—and to dopamine in particular. It plays a part in movement, motivation, mood and memory. And as Stephanie's tale hints, it also has a dark side. The neurotransmitter is implicated in addiction, schizophrenia, hallucinations and paranoia. Yet dopamine is best known for its role in *pleasure*. In the popular press, dopamine is delight; the brain's code word for bliss; the stuff that makes psychoactive drugs dope. Articles and documentaries describe dopamine as what makes life worth living, the chemical that permits every enjoyable moment to be savored, the "hit" everyone is chasing whether through social media, psychoactive substances, sports, food, sex or status.

But it may be time to rethink these ideas. Nora Volkow, director of the National Institute on Drug Abuse and a longtime researcher of this neurotransmitter, would like to set the record straight: "Dopamine is *not* the pleasure molecule in the simple, direct way it is typically portrayed in the media," she says. "Its function is much more nuanced."

Today the precise nature of dopamine is a matter of much controversy. Some researchers argue that dopamine, when acting within what has become known as the brain's reward system, signals desire. Others claim that it helps the brain predict rewards and direct behavior accordingly. A third group splits the difference, saying both explanations can be valid. Ironically, if there is anything scientists now agree on about this neu-

rotransmitter it is that dopamine *does not* neurologically define joy. Instead this little molecule may unlock the intricate mystery of what drives us.

Missing Motivation

In 1978 Roy Wise, then at Concordia University in Quebec, published a seminal paper on dopamine. He depleted levels of the neurotransmitter in rats with antipsychotic medications and found that the rats would stop working to receive yummy foods or desirable drugs such as amphetamine. The animals could still make the movements needed to obtain what they should have craved, which suggested that their behavior changed because the experience was no longer rewarding. Dopamine, at least when acting in a circuit located near the middle of the brain, seemed to be necessary for anything to feel good.

Over the next decade, data in support of Wise's idea only grew. So when neuroscientist Kent C. Berridge began researching dopamine at the University of Michigan around that time, he believed, like most of his colleagues, that it was a "pleasure" signal. Berridge's own work was focused on facial expressions of pleasure, which are surprisingly congruent among mammals. Even rats will avidly lick their lips when they receive sweet food and open their mouth in disgust after encountering a bitter taste—as will human babies. Typically mammalian expressions of satisfaction intensify when, for example, a hungry rat receives an especially tasty treat or a thirsty rat finally drinks water. Berridge thought that studying and measuring these responses could further confirm the idea that dopamine means pleasure to the brain.

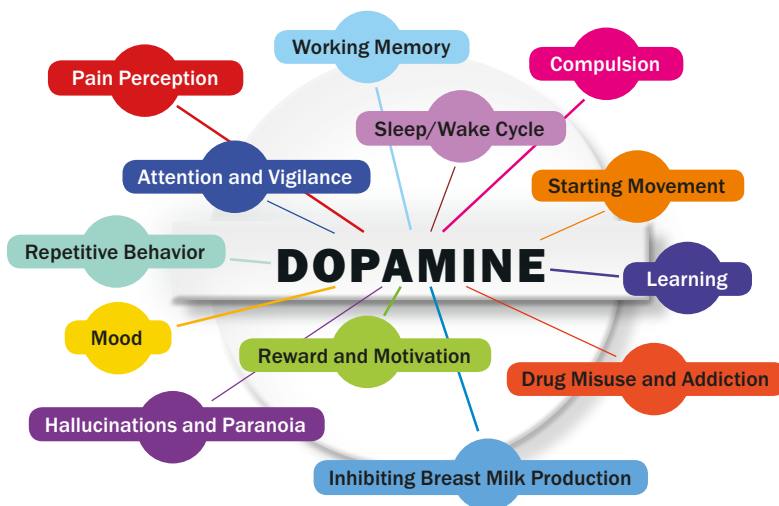
His colleague at the University of Michigan, neuroscientist Terry Robinson, had been using a neurotoxin to destroy dopamine neurons and create rats that modeled severe symptoms of Parkinson's. Berridge decided to give sweet foods to these rodents and see if they appeared pleased. He expected that their lack of dopamine would deny them this response. Because they

were so dopamine-depleted, Robinson's rats rarely moved if left alone. They did not seek food and had to be fed artificially. "They wouldn't want to eat or drink anything," Berridge says. Unexpectedly, however, their facial reactions were completely normal—they continued to lick their lips in response to something sweet and grimace at a bitter meal.

They tried again and again, but Berridge and his colleagues got the same results. When they conducted an experiment that basically created the opposite conditions—by ramping up dopamine levels in rats using electrodes implanted in appropriate

The Dope on Dopamine

Despite a long-standing association with pleasure, this neurotransmitter is linked to many other facets of experience:



regions—the rats did not lick their chops more eagerly when eating, as the "dopamine is pleasure" theory predicted. Indeed, sometimes the animals actually seemed less pleased when they scarfed down their sweets. Nevertheless, they kept eating far more voraciously than normal.

The researchers were puzzled. Instead of producing pleasure, dopamine seemed to drive desire. Desire itself can be enjoyable in small doses—but in the long run, if it is not satisfied, it is just the opposite. Eventually Berridge and Robinson realized that the pleasure involved in seeking a reward and that of actually obtaining it must be distinct. They labeled the drive that dopamine seemed to induce as "wanting" and called the joy of being satiated, which did not seem to be connected with dopamine, "liking."

This dissociation fit with studies of Parkinson's patients. They are still, after all, able to enjoy life's ups but often have problems with motivation. Perhaps the most vivid example of this occurred in the early 20th century, when an epidemic of encephalitis lethargica left thousands of people with an especially severe parkinsonian condition. Their brains were so depleted of dopamine that they were unable to initiate movement and were essentially "frozen in place" like living statues. (The film *Awakenings*, which starred Robin Williams as neurologist Oliver

FAST FACTS

MISPLACED MOTIVATION?

- 1 The neurotransmitter dopamine plays an essential role in movement and motivation; its association with pleasure may be somewhat misunderstood.
- 2 Several studies involving animals suggest that the molecule is linked to wanting to pursue a given activity but does not necessarily correlate to liking the experience.
- 3 A new theory posits that the brain uses dopamine in making predictions of how rewarding an experience will be. The neurotransmitter's levels are higher when an experience exceeds expectations, informing how much joy we derive.

“DOPAMINE IS NOT THE PLEASURE MOLECULE.... ITS FUNCTION IS MUCH MORE NUANCED.”

**—NORA VOLKOW, DIRECTOR,
NATIONAL INSTITUTE ON DRUG ABUSE**

Sacks, was based on the doctor’s 1973 memoir of treating such patients.) But a sufficiently strong external stimulus could spark action for people with this condition. In one case cited by Sacks, a man who typically sat motionless in his wheelchair on the beach saw someone drowning. He jumped up, rescued the swimmer and then returned to his prior rigidly fixed position. One of Sacks’s own patients would sit silent and still unless thrown several oranges, which she would then catch and juggle.

Mirapex, the drug that Stephanie took, is one of a class of medications known as dopamine agonists used to re-enable movement and motivation. Dopamine receptors perceive these drugs as the real thing and react accordingly. Consequently, the medications can offer excellent relief from tremors, rigidity and other movement problems. But the drugs can also have some destructive and distressing side effects.

Stephanie went from essentially not having enough motivation to having too much—or, at least, the motivation that the drug ignited was misdirected. In addition to overeating, her problems on dopamine agonists included gambling, an obsession with her iPhone, compulsive online shopping and intrusive sexual desires. Subjectively, the experiences she described were nearly identical to those reported by people with more typically caused addictions. In the case of lottery-ticket buying, it was like being programmed into an infinite loop. Whether she won or lost, there was always a need to do it again. As Arnie Wexler, a former compulsive gambler and author of a 2014 book on the subject called *All Bets Are Off*, puts it, “The difference between normal people and compulsive gamblers is we chase wins and we chase losses, and there’s never enough to win and never enough to lose.”

Many people with addictions experience an escalation in desire that, similarly, is not accompanied by a similar increase in enjoyment. “The want, the desire, was so much that I never really thought about, ‘Did I end up liking it at the end?’ because it didn’t matter,” Stephanie says. That experience beautifully describes what Berridge and Robinson call the “incentive sensitization” theory of dopamine action, which they introduced in 1993 and which has been bolstered by more recent studies.

What dopamine is “really doing,” Berridge says, “is taking things you encounter, little cues, things you smell and hear, and if they have a motivational significance, [it] can magnify that significance,” raising the incentive to pursue them. Placing dopamine directly into the nucleus accumbens of rats, he notes, will make them work two to three times harder to get what they crave, but it will not amplify the pleasurable experience of rewards once they are obtained.



Humans, orangutans and rats all express their delight in a sweet snack by licking their lips. This common code enabled researchers to assess animals’ joy in dopamine experiments.

Prediction Engines

More recently, other researchers have focused on a different function for dopamine in the brain’s motivational systems. They say that the brain uses dopamine in these regions not so much as a way to spur behavior through wanting but as a signal that predicts which actions or objects will reliably provide a reward. “It encodes the difference between what you’re getting and what you have expected,” says neuroscientist Wolfram Schultz, now at the University of Cambridge, who published a seminal paper on what is now known as the “reward prediction error” theory of dopamine in 1997.

In a series of experiments begun in the 1980s, Schultz and

THE AUTHOR

MAIA SZALAVITZ is a journalist and author or co-author of seven books. Her latest, *New York Times* best seller *Unbroken Brain: A Revolutionary New Way of Understanding Addiction*, was published in April 2016 by St. Martin’s Press.

his colleagues showed that when monkeys first get something pleasant—in this case, fruit juice—their dopamine neurons fire most intensely when they drink the liquid. But once they learn that a cue like a light or a sound predicts the delivery of delicious stuff, the neurons fire when the cue is perceived, not when the reward is received. This response changes when the value of the reward shifts. If a reward is bigger or better than expected, the dopamine neurons fire more in response to this happy surprise; if it is nonexistent or smaller than anticipated, dopamine levels crash.

In a 2016 study, Schultz and his colleagues asked 27 partici-

insight from past mistakes. Schultz therefore sees dopamine as playing a role in how we learn what to seek and what to avoid.

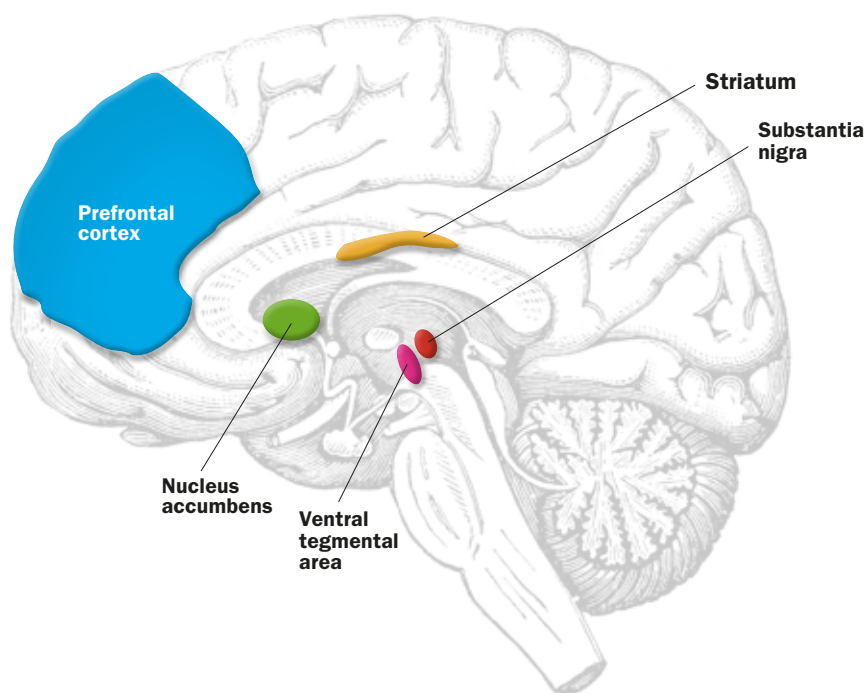
In this view, dopamine does not signify how pleasant an experience will be but how much value it has to the organism at that particular moment. Schultz notes that dopamine neurons do not distinguish among different types of reward. “They’re only interested in the value,” he says. “They don’t care whether it’s food reward or liquid reward or money. They’re specific about the prediction error, but they don’t care what the reward is.”

Schultz suggests dopamine serves as a common currency system for desire. For example, when the brain receives a signal that the body needs water, the value of water for that individual at that time should rise. Because this makes a cold drink more attractive, quenching thirst will be prioritized, avoiding dehydration. Yet, Schultz explains, “if I fall in love, then all my other rewards become relatively less valuable.” A glass of water will pale in comparison to a chance to be with the beloved.

From this perspective, it is easy to see why dopamine would be critical to addiction. If drugs or other compelling pleasures alter the way the reward system determines what is valuable, the addictive behavior will be given top priority and motivation will shift accordingly. Seeing dopamine this way can also explain a number of psychological phenomena. Consider how people typically prefer a smaller reward now to a bigger one later, what economists term “delay discounting.” This shift occurs because as rewards recede into the distant future, they are far less salient than those that are just about to be received—and are represented by progressively lower amounts of dopamine.

Moreover, if dopamine codes reward prediction error, it could also account for the so-called hedonic treadmill, that sadly

universal experience in which what initially makes us ache with desire, over time becomes less alluring, requiring a greater intensity of experience, new degree of novelty or higher dose to achieve the same joy. (You buy a new car, but driving it soon becomes routine and you start to crave a fancier one.) According to reward prediction error theory, when there is no prediction error—when something is just as pleasant as expected, no more or less—dopamine levels do not budge. But your current pleasure may increase expectations for the next experience, Shultz says, “so the prediction error is less high and your reaction is less strong.” (This logic would also confirm the 1965 hypothesis by Mick Jagger et al. regarding the low probability of getting long-term satisfaction.)



Longing in the Brain

Signals that originate in dopamine-rich structures in the midbrain, such as the nucleus accumbens, and travel to the prefrontal cortex have long been seen as “pleasure pathways.” More recent work, however, suggests that dopamine stimulates desire or wanting rather than delight.

pants undergoing magnetic resonance imaging to look at a computer screen with a series of rectangles, each representing a “range” of money (for example, £0 to £100), without specific values indicated. A crosshair landed somewhere along a rectangle to indicate a cash prize. In several trials, people would guess at and then (virtually) receive the corresponding amount. Meanwhile the researchers tracked activity in select dopamine hotspots. They found that activity in the substantia nigra and ventral tegmental area, neighboring regions in the midbrain, was linked to people’s prediction errors—whether they were pleasantly surprised or disappointed by the prize. In addition, the activity in this area over the course of the experiment related to how well participants adapted their estimates as they gained

DOPAMINE'S ACTION MAY EXPLAIN WHY WHEN WE ARE DISAPPOINTED, IT'S COMFORTING TO LEARN THAT THINGS COULD HAVE BEEN WORSE.

Other researchers have begun putting Schultz's ideas to the test. In 2016 in the *Proceedings of the National Academy of Sciences USA*, neuroscientist Read Montague of Virginia Tech and his colleagues published findings involving 17 people with Parkinson's who had brain implants that could measure changes in dopamine in the striatum, another midbrain area linked to rewarding experiences. They found that dopamine signaling might be even more nuanced than making a simple calculation that compares experience with expectations.

In the experiment, the patients played a game that involved betting on a simulated market. While playing, they considered the possible outcomes of various choices and later evaluated their decisions based on what had actually occurred. Here the dopamine signals that were recorded did not track a simple reward prediction error. Instead they varied by how the bets came in compared with how the investment would have fared if they had chosen differently. In other words, if someone won more than she expected but could have won *even* more if she had made a different choice, she had less dopamine release than if she had not known there was a way she could do even better.

In addition, if someone lost a few bucks but could have lost a lot more if he had made a different choice, dopamine would rise somewhat. This finding explains why knowing that "it could have been worse" can make what would otherwise feel awful into a positive—or at least less dire—experience.

Putting It All Together

Although some scientists view the reward prediction error theory and Robinson and Berridge's incentive sensitization theory as incompatible, they do not directly falsify each other. Indeed, many experts think that each captures some element of the truth. Dopamine might signal wanting in some neurons or circuits and could signify reward prediction error in others.

Alternatively, these functions may operate on different timescales—as suggested by a 2016 study in rats conducted by scientists at the University of Michigan (colleagues of Berridge and Robinson). The study, published in *Nature Neuroscience*, found that changes in dopamine levels from second to second were congruent with dopamine as an indicator of value, which supports the reward prediction error hypothesis. Longer-term changes, over the course of minutes, however, were linked with changes in motivation, which bolsters the incentive sensitization theory.

While taking dopamine agonists, Stephanie was certainly

aware that her priorities had shifted in uncomfortable ways—but at the time she accepted this because her addictive behavior seemed, as she put it, like "the right thing to do." Our feelings, in a sense, are decision-making algorithms that evolved to guide behavior toward what was historically most

likely to promote survival and reproduction. Pleasure can cue us to repeat activities such as eating and sex; fear drives us away from potential harm. But if the brain regions that determine what you value go askew, it can be extremely difficult to change your behavior because these areas will make you "want" to continue and will also make the addictive behavior "feel" right.

When Stephanie stopped taking Mirapex, all her addictive desires and behavior vanished overnight. In fact, not only did she no longer find her iPhone or buying lottery tickets attractive, they seemed at best of little interest or even actively repellent. She also lost the weight she had gained without much effort. Indeed, Daniel Weintraub, a psychiatrist at the University of Pennsylvania, says that her experience is typical of Parkinson's patients who develop impulse-control disorders while taking dopamine agonists, which is roughly 8 to 17 percent of people taking such drugs. The fact that stopping these drugs can end addictive behavior so abruptly and decisively shows how critical dopamine is in driving it.

A few years later, however, Stephanie's Parkinson's symptoms became worse, and she agreed to try another dopamine agonist. Not long after, she found herself spending hours online, looking at Web sites for people who wanted to have affairs or casual sex. She resisted the urges. "I couldn't do that to my husband," she explains. "Part of my brain still knew that was wrong."

Her prior experience with Mirapex also made a difference, she says: "I knew what to look for, which I didn't the first time around," so she stopped taking the drug. Although dopamine can modulate our drives, it is not the only determinant of what we do and what matters to us—as Stephanie's decisions demonstrate. Ultimately what we humans seek and value is a little more complicated than our fleeting desires. **M**

MORE TO EXPLORE

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THE STAMP OF POVERTY

Growing up in a poor family can leave a mark on the developing brain. Understanding how and why has important implications for educators and society

By John D. E. Gabrieli and Silvia A. Bunge

ILLUSTRATIONS BY ROB DOBI



Imagine that you are a child again. In this version of your childhood, you arrive at school hungry, tired and anxious. Your mother was not able to pay the rent this month. The cupboards are bare. A car alarm went off late last night, and it fell to you to soothe your baby brother back to sleep. You woke up early to take the bus across town, and by the time the school bell rings, you have so much on your mind that it is difficult to concentrate.

Myriad stressors collect and compound for children who grow up in poverty. Although their stories are all different, we know that the many challenges they face can have a lasting impact. In the U.S., one in four infants and toddlers lives below the federal poverty line.

Despite our societal desire to see education as an equalizer that elevates people from difficult circumstances, social scientists have known for some time that the truth is not so simple. The income of the family you are born into has a powerful effect on educational outcomes and, in turn, future job prospects and economic security. Education researcher Sean Reardon and his colleagues at Stanford University recently completed an analysis showing that children in school districts with high levels of poverty score an average of four grade levels below peers from the most affluent districts on tests of reading and math. And kids born to a low-income family have a far worse chance of getting a college degree than children born to a high-income family, in turn constricting economic and career opportunities.

As disquieting as these inequities may be, this

so-called income-achievement gap is not new. Educators and social scientists have been tracking the relation between school success and poverty for roughly half a century. Although there is now some evidence that the divide may be starting to narrow—after three decades of expansion—the pace of change is too slow to help this generation or even the next. In fact, it could take 60 to 110 years to close the gap at its current rate of change, according to a 2016 calculation by Reardon.

In the meantime, strong evidence has begun to emerge about how family income relates to the development of a child's brain. In essence, scientists are finding anatomical differences tied to poverty—and some of this variation has implications for education. Everything that is learned, after all, depends on the brain's plasticity, its ability to grow and change. The new discoveries, in turn, serve not only as an added call to action but may also fuel ideas about how to best intervene.

Building the Brain

At birth, we have a rich supply of both gray matter, which is primarily composed of cell bodies, and white matter, which encompasses the tracts of cablelike axons that transmit signals from one neuron to the next. We start out with more neural material than we strictly need. The brain is sculpted into a more efficient organ as we learn and grow, strengthening some networks, eliminating others.

From late childhood through early adulthood, a part of the brain called the neocortical gray matter steadily thins. This area comprises six layers of cortex that cover the brain and support perception,

FAST FACTS

THE BRAIN AND POVERTY

- 1 Several studies have now uncovered a link between socioeconomic status and brain development.
- 2 On average, children from lower-income families appear to have a thinner cortex in early childhood than their peers from more affluent homes.
- 3 Although the best strategy for mitigating the effects of early deprivation is prevention—in this case, tackling child poverty at a societal level—various research groups are implementing efforts to help kids in need.

SOURCES: CHILD POVERTY IN AMERICA 2015; NATIONAL ANALYSIS; CHILDREN'S DEFENSE FUND, SEPTEMBER 13, 2016 (children in poverty); U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES (poverty line); CHILD POVERTY AND INTERGENERATIONAL MOBILITY, BY SARAH FASS ET AL., NATIONAL CENTER FOR CHILDREN IN POVERTY, DECEMBER 2009 (poverty at age 35); INDICATORS OF HIGHER EDUCATION EQUITY IN THE UNITED STATES: 45 YEAR TREND REPORT, REVISED, PELL INSTITUTE FOR THE STUDY OF OPPORTUNITY IN EDUCATION AND PENN ALLIANCE FOR HIGHER EDUCATION AND DEMOCRACY, 2015 (college completion for bottom quartile); "IS COLLEGE WORTH IT? CLEARLY," BY DAVID LEONHARDT, IN THE UPSHOT, NEW YORK TIMES, PUBLISHED ONLINE MAY 27, 2014 (pay increase with college degree)

language, thought and action. Researchers believe this thinning reflects a massive pruning of cells and the connections between them. Also during this life stage, white matter develops in ways that improve the connectivity of large-scale networks across the brain.

Scientists have only recently begun to examine how socioeconomic status (SES) might influence the normal course of brain development. SES is a complex construct that is measured by combining educational attainment, income and occupation. There is substantial variation among individuals and families at every socioeconomic level, making it hard to generalize about an individual's experiences. In addition, disadvantages, where they exist, tend to co-occur or correlate with one another, so it is difficult to relate specific circumstances to particular outcomes. For example, very low SES or poverty is associated with poor health, family instability and high stress. It can also entail malnutrition, limited health care, modest language and intellectual stimulation at home, inferior schools and lowered social expectations. These conditions could all, in turn, affect neural and cognitive development.

Children in high-poverty school districts score four grade levels below peers in the wealthiest districts, a recent analysis found.

A classic series of experiments conducted in the 1960s at the University of California, Berkeley, proved that adverse early environments harm the brain in rodents. Neuroscientist Marian Diamond showed that rearing rats in an impoverished environment—lacking toys and opportunities to socialize—hampered their brain development and ability to learn.

Such studies would be unethical in humans, but a long-term follow-up of Romanian children who had been warehoused in an appalling system of state orphanages found similar outcomes. Begin-

INEQUALITY, BY THE NUMBERS

When economists calculate income inequality for nations, the U.S. has both the greatest private wealth and the greatest income inequality in the developed world. People born into the poorest families face many challenges.

14.5 million
children under age 18 live below the poverty line in the U.S.

45 percent of people who spend at least half their childhood in poverty will still live in poverty at age 35

\$24,300
is the federal poverty line for a family of four

77 percent is the chance that a child born in the upper-income quartile will complete college by age 24

1 in 3
Americans living in poverty are under the age of 18

9 percent is the chance that a child born in the bottom-income quartile will complete college by age 24. A college degree is associated with a 98 percent increase in hourly pay



Research links family income to variation in anatomy, especially in the cortex, which supports learning, thought and action.

ning in 2001, developmental psychologists Charles A. Nelson III of Harvard University, Nathan A. Fox of the University of Maryland and Charles H. Zeanah, Jr., of Tulane University compared kids who remained trapped in that system with those who escaped to foster care or adoption and found dire emotional and cognitive repercussions for the first group. They confirmed that the environment can shape cognitive and brain growth and showed that a supportive intervention can substantially ameliorate early privations.

Seeing the Difference

Most children growing up in poverty face some adversity, but it is rarely as extreme as the absence of human interaction and enrichment experienced by the Romanian orphans. Nevertheless, even lesser deprivation appears to alter brain development. In the past few years several large, high-quality studies using MRI have linked variation in a child's neuroanatomy with family income. In no area are the disparities more striking than in the cortex.

One of us (Gabrieli) has made this observation in his own laboratory at the Massachusetts Institute of Technology. He, Allyson Mackey and their colleagues compared cortical thickness among 58 eighth grade students from lower-income versus higher-income families. The results, published in 2015, revealed that the lower-income group had a thinner cortex in widespread regions of the brain. For all stu-

dents, regardless of income, a thicker cortex was associated with better scores on statewide tests of reading and math. This study, therefore, directly related family income, brain anatomy and educational achievement.

In the same year, cognitive neuroscientist Kim Noble of Columbia University and her colleagues published findings from an MRI examination of 1,099 children ages three through 20. They discovered that cortical surface area was larger in children with greater family income. Critically, they found that small differences in income among families earning less than \$50,000 a year were associated with relatively large differences in surface area. But this pattern did not hold true among kids from families who made more than \$50,000. These findings suggest a threshold model in which small disparities in earnings may matter greatly among lower-income individuals, but above a certain income level, these differences have less impact.

Also in 2015 Seth Pollak, a psychologist at the University of Wisconsin–Madison, published a study of 389 children and young adults, aged four to 22, that examined the relation between household poverty, academic performance and MRI data. He and his colleagues found that people with higher scores on cognitive and achievement tests had greater cortical volumes in the frontal and temporal lobes—and, as in the other studies, poorer children had less cortical gray matter (a finding that in all three studies was unrelated to race or ethnicity).

All of this work is correlational, so it is important to note that it cannot prove whether or not an impoverished environment *caused* these changes—or, for that matter, whether these differences in structure definitely translate into academic deficits. There are some remarkable students, for example, who do very well in school despite an impoverished background, and we do not know how their neural structure compares. It may resemble that of a more affluent child—or perhaps their brain can compensate, enabling equal academic performance despite differences in brain architecture.

The consistent finding that poverty is associated with a smaller cortex is notable, however, because we associate brain maturation from childhood through young adulthood with a thinning cortex. In fact, several studies have reported that better cognitive abilities are associated with a thinner cortex among adolescents at a given age. (These findings most likely involved children from higher-income families who are more likely to volunteer for research studies.)

THE AUTHORS

JOHN D. E. GABRIELI is a professor in the department of brain and cognitive sciences at the Massachusetts Institute of Technology and is director of the Athinoula A. Martinos Imaging Center at the McGovern Institute for Brain Research and the Gabrieli Laboratory, both at M.I.T.

SILVIA A. BUNGE is a professor in the department of psychology and at the Helen Wills Neuroscience Institute at the University of California, Berkeley, where she also directs the Building Blocks of Cognition Laboratory.

On the one hand, a reduced cortex may simply reflect the deleterious consequence of impoverished environments. On the other hand, it could reflect a protective adaptation to such environments. Accelerated thinning could perhaps diminish the influence of negative experiences on the developing brain. Preventing the brain from being shaped by harsh influences over the course of many years could be an evolutionarily adaptive response, helping a child to better cope in adverse conditions—but premature thinning could also reduce education’s influence on the developing brain.

A Question of Timing?

Researchers have been trying to determine when brain differences associated with SES first become apparent: Do they start in the womb or as an infant experiences more or less supportive environments after birth? In principle, brain imaging offers a novel way to answer these questions, but findings thus far have been inconsistent.

One 2015 study of 44 infants by cognitive neuroscientist Martha Farah of the University of Pennsylvania and her colleagues found that by one month of age, higher SES (defined by income and maternal education) was associated with larger cortical volume in girls. This finding suggests that differences emerge very early—although it is hard to know what such variation means.

Pollak and his colleagues, however, looked at infants aged five months to four years and in 2013 found that SES-related brain differences were minimal at early ages but increased over time. This gap does not grow indefinitely, however. Investigation later in life has yielded no evidence for widening brain differences after early childhood.

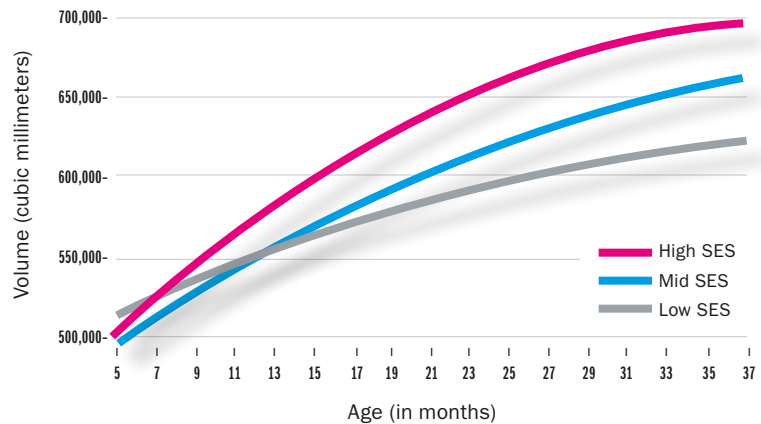
It is also important to consider the specific influences that may shape development during these years. Another study by Farah linked home environment to brain development. Researchers visited homes when children were four and then again at eight years of age, and both times they measured environmental stimulation, such as exposure to books, conversation, trips and music.

When the same group of kids reached adolescence, they were given MRI scans. The researchers found that a stimulating home at age four, but not at age eight, predicted greater cortical thickness in the frontal and temporal cortex. It may be that the home environment has a particularly powerful influence on brain development in the

early childhood years—or that by age eight, school and social peers exert greater influence than the home does.

It is also possible that, given the range of factors related to socioeconomic status, there may not be a single or simple answer to the question of when brain differences first emerge. Furthermore, there may not be a special or “critical” period of development that is uniquely potent in predicting long-term outcomes. It seems logical that early preventive help is more likely to be effective than remedial support after a child has fallen behind, but education occurs continuously through a child’s development and matters at all ages.

Total Gray Matter



Using MRI to track brain development in 77 infants, psychologists at the University of Wisconsin–Madison found that differences associated with socioeconomic status (SES) became increasingly pronounced over time. By age three, toddlers from low-income households showed significantly less gray matter than those raised in wealthier homes.

Finding Ways to Help

Early experience does not *determine* outcomes; it merely influences their probability. Given individual variation in response to adversity, we cannot and should not make assumptions about a child’s potential based on his or her background. The brain, after all, is plastic and continues to change with experience over a life span.

Yet the longer we wait to get started, the more intensive the effort we may need to counteract the effects of early adversity. The detriments associated with the Romanian orphanages, for example, were not as pronounced among kids placed into family



A number of research-based programs for disadvantaged kids are showing good results. Structured group play sessions, such as those offered at Childhaven in Seattle (left) or a Tools of the Mind classroom such as this one at Christina Seix Academy in Trenton, N.J. (right), can help boost executive functions, a crucial set of skills that includes problem solving, reasoning and planning.

foster care early in childhood. The best solution is therefore prevention, and the next best is remediation. That means that tackling income inequality—and particularly extreme child poverty—at the societal level is of paramount importance, and we hope that neuroscientific evidence can be a spur for shifting policy in that direction. Meanwhile there are some promising steps, inspired by the new findings, that we can take to mitigate the negative effects of indigence on children.

There are a number of ways people are trying to improve life outcomes for disadvantaged children—including efforts targeting factors such as sleep and nutrition, cognitive and academic skills, and even finance, career development and parenting strategies for parents and caregivers. Columbia's Noble and her colleagues, for example, have begun a pilot project in which they are testing whether cash transfers to low-income mothers will improve their child's environment and cognition and lower maternal stress. If the threshold model is correct, even modest financial assistance could make a big difference.

Applying techniques from neuroscience may yield unique insight into a given intervention's power. One example of an approach that has been assessed in part through brain measurements is the Kids in Transition to School (KITS) program, developed by psychologist Philip Fisher and his colleagues at the Oregon Social Learning Center, which works with children in foster care and youngsters from low-income families two months before the start of kindergarten and continues until two months after entry.

Aimed at boosting self-regulatory skills, as well

as early literacy and prosocial behavior, KITS includes 24 sessions of therapeutic play for children, as well as an eight-session workshop for caregivers. In the classroom, students practice skills such as sitting still and raising their hand, as well as cooperating with their peers. In the workshop, adults learn ways to establish routines with children and encourage good behavior.

Two-generation approaches are effective for many reasons, among them the fact that when parents are involved, children can be helped outside of class and they may not feel as singled out among their peers. In a paper published in 2013 Helen Neville, a cognitive neuroscientist at the University of Oregon, and her colleagues compared a parent-and-child intervention based on KITS with an intervention focused solely on kids. They found that the combined approach did a better job of boosting nonverbal IQ and language skills. This result was supported by electroencephalography (EEG) findings indicating that the children had a bigger improvement in their brain's capacity to filter out distracting information while focusing on a task.

Both of us are directly involved in testing other interventions for children in poverty that involve their parents and caregivers. As part of the Boston Charter Research Collaborative, Gabrieli works with teachers at six charter school management organizations, serving nearly 7,000 inner-city students in the metropolitan area. The teachers describe their challenges, and researchers at Harvard and M.I.T. offer evidence-based solutions; together they implement and evaluate these programs. Some of the participating students come

COURTESY OF CHILDAHVEN (left); COURTESY OF TOOLS OF THE MIND (right)

for brain imaging before and after an intervention so that beneficial brain plasticity can be visualized.

Neuroimaging can also pinpoint cognitive targets for an intervention. The executive functions, for example, are a suite of skills that help people focus on a task, regulate feelings and behaviors, and consider possible consequences before making a decision. They not only increase the odds of staying in school but also appear to be highly vulnerable to poverty. Indeed, executive functions are associated with the prefrontal cortex, an area that shows clear differences in imaging studies that compare children of wealth with those of poverty.

Bunge is involved in the Frontiers of Innovation (FOI) network, established by the Center on the Developing Child at Harvard. This group of researchers and practitioners at multiple sites around the U.S. identifies and develops promising approaches for assisting parents and other caregivers of young children living in adversity. Through FOI, Bunge's team at U.C. Berkeley has been collaborating with Seattle-based Childhaven, which provides therapeutic services to children under age six who have suffered neglect or maltreatment at home. Pilot data from this work suggest that simple classroom activities, such as structured group play that requires children to follow explicit rules and take turns with their classmates, can begin to boost executive functions within 10 weeks.

Several other approaches have shown success in strengthening these functions. One example is the Tools of the Mind curriculum, an alternative to traditional kindergarten developed at Metropolitan State University of Denver by psychologists Elena Bodrova and Debora Leong. The curriculum focuses on building executive functions through “scaffolded” play, which involves targeted interactions with peers and teachers. In 2014 psychologists Clancy Blair and Cybele Raver of New York University found this program was especially beneficial in high-poverty preschools.

What Comes Next?

Although the nature of brain differences was unknown until the past decade, it had to be expected that the profound disparities in educational, occupational and health outcomes associated with childhood poverty or affluence would be reflected in the brain's development. In many ways, the findings complement the long-standing research into the income-achievement gap.

Early findings suggest certain classroom activities can boost cognitive functions vulnerable to poverty within 10 weeks.

Yet this work also hints at a special role for neuroscience, beyond descriptive imaging. Monitoring the progress of a particular approach with EEG, as well as behavioral measures, for instance, can offer a fast and revealing indicator of its strengths or failings. Furthermore, the nature of neural differences associated with SES is instructive. If longitudinal evidence supports the idea that more rapid cortical thinning occurs in children raised in poverty, then developing strategies to slow such thinning could be helpful.

Ultimately individual children will respond in varied ways to any given intervention. The challenge is to develop personalized solutions that are not overly expensive or time-consuming for educators. Broadly speaking, the most beneficial programs will be intensive (involving multiple, regular sessions or spanning several years), engage a range of skills in diverse ways, and incorporate not only children and educators but also caregivers and the home environment. Best of all would be public policies and societal changes that take aim at child poverty and income inequality.

Children from disadvantaged backgrounds face many challenges, but thanks in part to the remarkable power of neuroplasticity, no one's story is predetermined. Our hope is that the new brain-based findings may inspire and guide solutions to help these kids flourish and thrive. **M**

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THE MIND OF AN OCTOPUS

Eight smart limbs plus a big brain add up to a weird and wondrous kind of intelligence

By Peter Godfrey-Smith



Adapted from *Other Minds: The Octopus, the Sea, and the Deep Origins of Consciousness*, by Peter Godfrey-Smith. Copyright © 2016 by Peter Godfrey-Smith. Published by arrangement with Farrar, Straus and Giroux, LLC (US), HarperCollins (UK).

US





Someone is watching you, intently, but you can't see them. Then you notice, drawn somehow by their eyes. You're amid a sponge garden, the seafloor scattered with shrublike clumps of bright orange sponge. Tangled in one of these sponges and the gray-green seaweed around it is an animal about the size of a cat. Its body seems to be everywhere and nowhere. The only parts you can keep a fix on are a small head and the two eyes. As you make your way around the sponge, so, too, do those eyes, keeping their distance, keeping part of the sponge between the two of you. The creature's color perfectly matches the seaweed, except that some of its skin is folded into tiny, towerlike peaks with tips that match the orange of the sponge. Eventually it raises its head high, then rockets away under jet propulsion.

A second meeting with an octopus: this one is in a den. Shells are strewn in front, arranged with some pieces of old glass. You stop in front of its house, and the two of you look at each other. This one is small, about the size of a tennis ball. You reach forward a hand and stretch out one finger, and one octopus arm slowly uncoils and comes out to touch you. The suckers grab your skin, and the hold is disconcertingly tight. It tugs your finger, tasting it as it pulls you gently in. The arm is packed with sensors, hundreds of them in each of the dozens of suckers. The arm itself is alive with neurons, a nest of nervous activity. Behind the arm, large round eyes watch you the whole time.

Octopuses and their relatives (cuttlefish and squid) represent an island of mental complexity in the sea of inverte-

brate animals. Since my first encounters with these creatures about a decade ago, I have been intrigued by the powerful sense of engagement that is possible when interacting with them. Our most recent common ancestor is so distant—more than twice as ancient as the first dinosaurs—that they represent an entirely independent experiment in the evolution of large brains and complex behavior. If we can connect with them as sentient beings, it is not because of a shared history, not because of kinship, but because evolution built minds twice over. They are probably the closest we will come to meeting an intelligent alien.

Comparing Brains

Octopuses, cuttlefish and squid belong to a class of marine mollusks called



cephalopods, along with now extinct creatures called ammonites and belemnites. The fossil record of octopuses remains skimpy. As the only cephalopods without an external or internal shell and no hard parts except for a beak, they do not preserve well. But at some stage during their evolution, they radiated—around 300 species are known at present, including deep-sea as well as reef-dwelling forms. They range from less than an inch in length to the giant Pacific octopus, which weighs in at 100 pounds and spans 20 feet from arm tip to arm tip.

FAST FACTS

DEEP-SEA THINKERS

- 1 Octopuses and their kin (cuttlefish and squid) stand apart from other invertebrates, having evolved with much larger nervous systems and greater cognitive complexity.
- 2 The majority of neurons in an octopus are found in the arms, which can independently taste and touch and also control basic motions without input from the brain.
- 3 Octopus brains and vertebrate brains have no common anatomy but support a variety of similar features, including forms of short- and long-term memory, versions of sleep, and the capacities to recognize individual people and explore objects through play.

PRECEDING PAGES: HENRIK SORENSEN/Getty Images;
THIS PAGE: HILARY MOORE/Getty Images



GETTY IMAGES

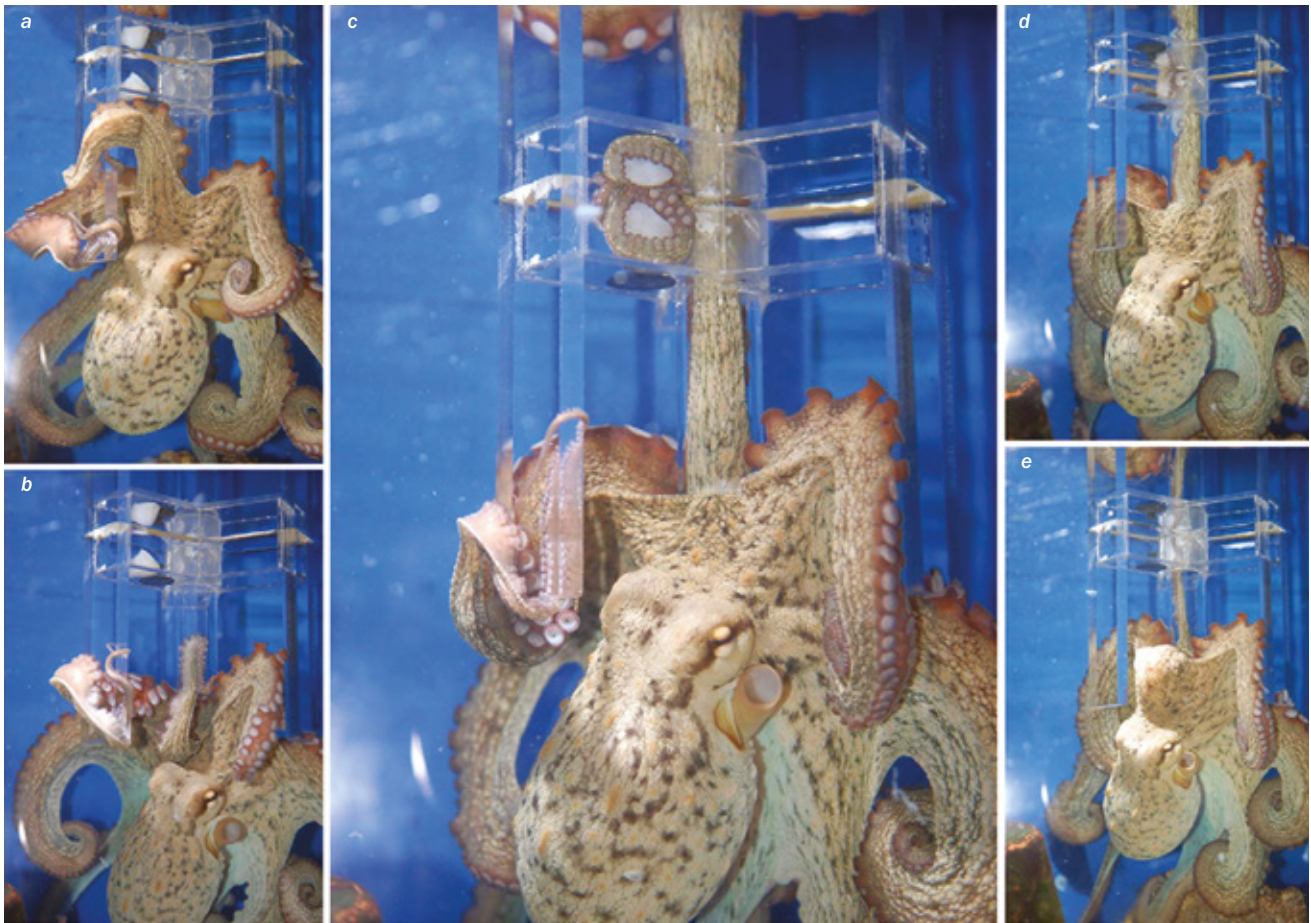
As the cephalopod body evolved toward these modern forms—internalizing the shell or losing it altogether—another transformation occurred: some of the cephalopods became smart. “Smart” is a contentious term to use, so let’s begin cautiously. First of all, these animals evolved large nervous systems, including large brains. Large in what sense? A common octopus (*Octopus vulgaris*) has about 500 million neurons in its body. That is a lot by almost any standard. Human beings have many more—something nearing 100 bil-

lion—but the octopus is in the same range as various mammals, close to the range of dogs, and cephalopods have much larger nervous systems than all other invertebrates.

Absolute size is important, but it is usually regarded as less informative than relative size—the size of the brain as a fraction of the size of the body. This tells us how much an animal is “investing” in its brain. Octopuses also score high by this measure, roughly in the range of vertebrates, though not as high as mammals. Biologists regard all these

assessments of size, however, as only a very rough guide to the brainpower an animal has. Some brains are organized differently from others, with more or fewer synapses, which can also be more or less complicated. The most startling finding in recent work on animal intelligence is how smart some birds are, especially parrots and crows. Birds have quite small brains in absolute terms, though very high-powered ones.

When we try to compare one animal’s brainpower with another’s, we also run into the problem that there is



An octopus's arm can taste, touch and move without oversight from the brain. To test if the brain also has centralized, top-down control over the limbs, scientists designed a transparent maze. To reach a treat in the upper left compartment (a and b), the animals had to send an arm out of the water (c), losing guidance from their chemical sensors. They then had to rely on their eyes to direct the arm (d). Most succeeded (e).

no single scale on which intelligence can be sensibly measured. Different animals are good at different things, as makes sense given the different lives they live. When cephalopods are compared with mammals, the lack of any common anatomy only increases the difficulties. Vertebrate brains all have a common architecture. But when vertebrate brains are compared with octopus brains,

THE AUTHOR

PETER GODFREY-SMITH is a Distinguished Professor of philosophy at the Graduate Center, City University of New York, and a professor of history and philosophy of science at the University of Sydney in Australia.

all bets—or rather all mappings—are off. Octopuses have not even collected the majority of their neurons inside their brains; most of the neurons are in their arms.

Given all this, the way to work out how smart octopuses are is to look at what they can do. Octopuses have done fairly well on tests of their intelligence in the laboratory, without showing themselves to be Einsteins. They can learn to navigate simple mazes. They can use visual cues to discriminate between two familiar environments and then take the best route toward some reward. They can learn to unscrew jars to obtain the food inside—even from the inside out. But octopuses are slow learners in all these contexts. Against this background of mixed experimental results, however,

there are countless anecdotes suggesting that a lot more is going on.

Escape and Thievery

The most famous octopus tales involve escape and thievery, in which roving aquarium octopuses raid neighboring tanks at night for food. Those stories—the basis for octopus hijinks in the 2016 Disney-Pixar film *Finding Dory*—are not especially indicative of high intelligence. Neighboring tanks are not so different from tide pools, even if the entrance and exit take more effort. But here is a behavior I find more intriguing: in at least two aquariums, octopuses have learned to turn off the lights by squirting jets of water at the bulbs and short-circuiting the power supply. At the University of Otago in New Zealand, this game became so

FROM "OCTOPUS VULGARIS USES VISUAL INFORMATION TO DETERMINE THE LOCATION OF ITS ARM," BY TAMAR GUTNICK ET AL., IN *CURRENT BIOLOGY*, VOL. 21, NO. 6, MARCH 22, 2011

The octopus, an independent experiment in the evolution of large brains, is the closest we will come to meeting an intelligent alien.

expensive that the octopus had to be released back to the wild.

This story illustrates a more general fact: octopuses have an ability to adapt to the special circumstances of captivity and to their interactions with human keepers. Anecdotally at least, it has long appeared that captive octopuses can recognize and behave differently toward individual human keepers. In the same lab in New Zealand that had the “lights-out” problem, an octopus took a dislike to one member of the staff, for no obvious reason. Whenever that person passed by on the walkway behind the tank, she received a half-gallon jet of water down the back of her neck.

Neuroscientist Shelley Adamo of Dalhousie University in Nova Scotia also had one cuttlefish that reliably squirted streams of water at all new visitors to the lab but not at people who were often around. In 2010 the late biologist Roland C. Anderson and his colleagues at the Seattle Aquarium tested recognition in giant Pacific octopuses in an experiment that involved a “nice” keeper who regularly fed eight animals and a “mean” keeper who touched them with a bristly stick. After two weeks, all the octopuses behaved differently toward the two keepers, confirming that they can distinguish among individual people, even when they wear identical uniforms.

Philosopher Stefan Linquist of the University of Guelph in Ontario, who once studied octopus behavior, puts it like this: “When you work with fish, they have no idea they are in a tank, somewhere unnatural. With octopuses it is totally different. They know that they are inside this special place, and you are outside it. All their behaviors are affected by their awareness of captivity.” Linquist’s octopuses would mess around with their tank and deliberately plug the outflow valves by poking in their arms,

perhaps to increase the water level. Of course, this flooded the entire lab.

The tales of octopuses squirting experimenters reminded me of something I had seen myself. Captive octopuses often try to escape, and when they do, they seem unerringly able to pick the one moment you are not watching them. I

thought I might be imagining this tendency, until I heard a talk a few years ago by marine biologist David Scheel of Alaska Pacific University, who works with octopuses full-time. He, too, said that octopuses seem to track in subtle ways whether he is watching them or not, and they make their move when he

Embodied Wisdom?

The octopus is sometimes said to be a good illustration of the importance of a theoretical movement in psychology known as embodied cognition. One of its central ideas is that our body, rather than our brain, is responsible for some of the “smartness” with which we handle the world. The joints and angles of our limbs, for example, make motions such as walking naturally arise. Knowing how to walk is partly a matter of having the right body.

But the doctrines of the embodied cognition movement do not really fit well with the strangeness of the octopus’s way of being. Defenders of embodied cognition often say that the body’s shape and organization encode information. But that requires that there be a shape to the body. An octopus can stand tall on its arms, squeeze through a hole little bigger than one of its eyes, become a streamlined missile or fold itself to fit into a jar.

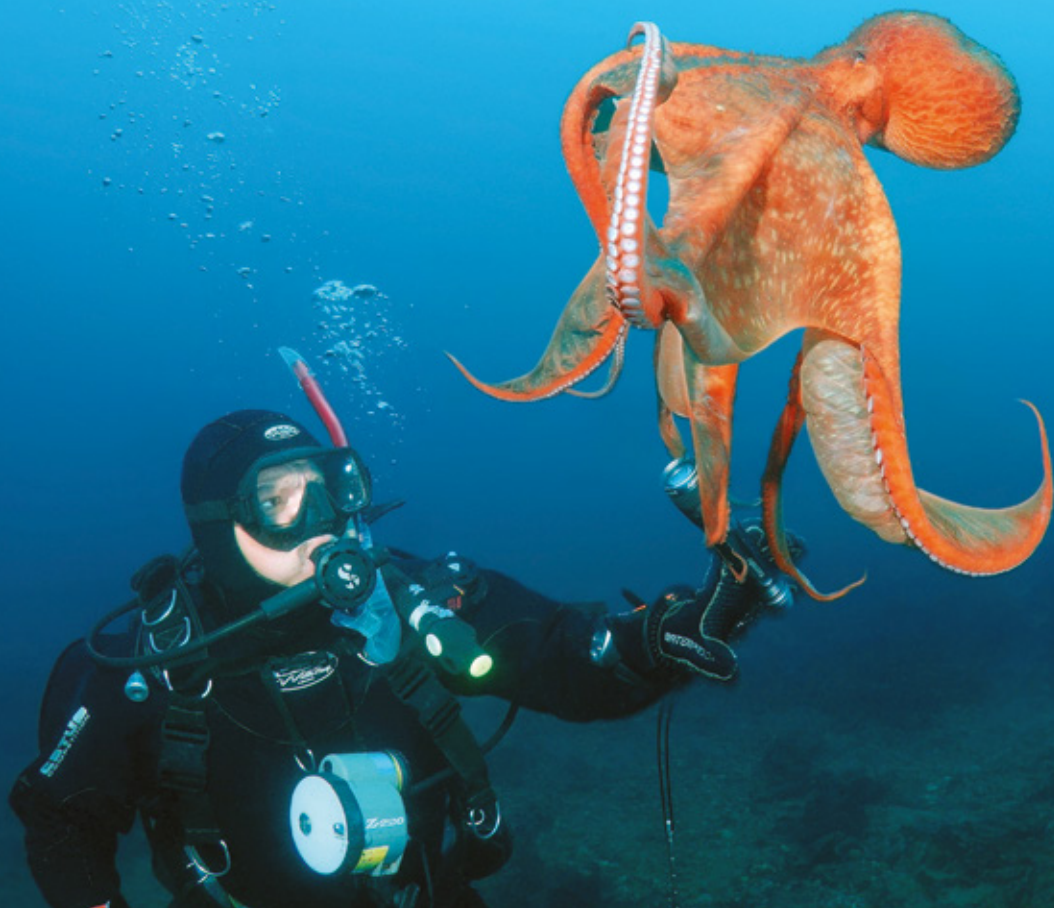
Further, in an octopus, it is not clear where the brain itself begins and ends. The octopus is suffused with nervousness; the body is not a separate thing that is controlled by the brain or nervous system. The usual debate is between those who see the brain as an all-powerful CEO and those who emphasize the intelligence stored in the body itself. But the octopus lives outside both the usual pictures.

It has a body—but one that is protean, all possibility; it has none of the costs and gains of a constraining and action-guiding body. The octopus lives outside the usual body/brain divide.

—P.G.-S.

With no hard body parts apart from a beak, an octopus can morph into a dazzling array of shapes and squeeze through openings only slightly bigger than one of its eyes.





When you approach an octopus in the wild, it is not unusual for the animal to send out one of its arms to inspect you. The arm's suckers—each of which may contain 10,000 neurons—latch on tightly, trying to pull you in closer and taste you at the same time.

is not. I suppose this makes sense as a natural behavior in octopuses; you want to make a run for it when the barracuda is not looking at you. But the fact that octopuses can so quickly do this with humans—both with scuba mask and without—is impressive.

Another octopus behavior that has made its way from anecdote to experimental investigation is play. An innovator in cephalopod research, Jennifer Mather of the University of Lethbridge in Alberta, along with Anderson, did the first studies of this behavior, and it has now been investigated in detail. Some octopuses—and only some—will spend time blowing pill bottles around their tank with their jet, “bouncing” the bottle back and forth on the stream of water coming from the tank’s intake

valve. In general, the initial interest an octopus takes in any new object is gustatory—can I eat it? But once an object is found to be inedible, that does not always mean it is uninteresting. Work by Michael Kuba, now at the Okinawa Institute of Science and Technology in Japan, has confirmed that octopuses can quickly tell that some items are not food and are often still quite interested in exploring and manipulating them.

Thinking on Their Feet

Let’s look more closely now at how the nervous system behind these behaviors evolved. The history of large brains has, very roughly, the shape of a letter Y. At the branching center of the Y is the last common ancestor of vertebrates and mollusks—some 600 million years ago. That ancestor was probably a flattened, wormlike creature with a simple nervous system. It may have had simple eyes. Its neurons may have been partly bunched together at its front, but there would

not have been much of a brain there.

From that stage the evolution of nervous systems proceeds independently in many lines, including two that led to large brains of different design. On our lineage, the chordate design emerges, with a cord of nerves down the middle of the animal’s back and a brain at one end. This design is seen in fish, reptiles, birds and mammals.

On the other side, the cephalopods’ side, a different body plan evolved and a different kind of nervous system. Invertebrates’ neurons are often collected into many ganglia, little knots that are spread through the body and connected to one another. The ganglia can be arranged in pairs, linked by connectors that run along the body and across it, like lines of latitude and longitude. This is sometimes called a ladderlike nervous system.

As cephalopods evolved, some ganglia became large and complex, and new ones were added. Neurons concentrated

Octopuses have not even collected the majority of their neurons inside their brains; most of their neurons are in their arms.

at the front of the animal, forming something more and more like a brain. The old ladderlike design was partly submerged, but only partly. For instance, in an octopus, the majority of neurons are in the arms themselves—nearly twice as many in total as in the central brain. The arms have their own sensors and controllers. They have not only the sense of touch but also the capacity to sense chemicals—to smell or taste. Each sucker on an octopus's arm may have 10,000 neurons to handle taste and touch. Even an arm that has been surgically removed can perform various basic motions, such as reaching and grasping.

The internal coordination of each arm can be quite graceful, too. When an octopus pulls in a piece of food, the grasping by the very end of the arm creates two waves of muscle activation, one heading inward from the tip and the other heading outward from the base. Where these two waves meet, a joint is formed that is something like a temporary elbow. The nervous systems in each arm also include loops in the neurons (recurrent connections, in the jargon) that may give the arm a simple form of short-term memory, although it is not known what this system does for the octopus.

How does an octopus's brain relate to its arms? Early work looking at both behavior and anatomy gave the impression that the arms enjoyed considerable independence. As Roger T. Hanlon and John B. Messenger put it in their 1996 book *Cephalopod Behaviour*, the arms seemed “curiously divorced” from the brain, at least in the control of basic motions. But octopuses can pull themselves together in some contexts. As I mentioned earlier, when you approach an octopus in the wild, in at least some species the octopus sends out one arm to inspect you—behavior that suggests a kind of deliberateness, an action guided by the brain.

In fact, some kind of mixture of localized and top-down control might be at work. The best experimental research I know that bears on this topic comes out of the lab of neurobiologist Binyamin Hochner of the Hebrew University of Jerusalem. In 2011 researchers Tamar Gutnick and Ruth Byrne, along with Hochner and Kuba, conducted a very clever experiment to test whether an octopus could learn to guide a single arm along a mazelike path to a specific place to obtain food. The task was set up so that the arm's own chemical sensors would not suffice to guide it to the food; the arm would have to leave the water at one point to reach the target location. But the maze walls were transparent, so the target location could be seen. The octopus would have to guide an arm through the maze with its eyes.

It took a long while for the octopuses to learn to do this, but in the end, nearly all the animals tested succeeded. The eyes can guide the arms. At the same time, the paper also noted that when octopuses are doing well with this task, the arm that is finding the food appears to do its own local exploration as it goes, crawling and feeling around. So it seems that two forms of control are operating in tandem: there is central control of the arm's overall path, via the eyes, combined with a fine-tuning of the search by the arm itself.

Common Ground

Despite their many differences, cephalopods bear some striking similarities to vertebrates. For instance, vertebrates and cephalopods separately evolved “camera” eyes, with a lens that focuses an image on a retina. The capacity for learning of several kinds is also seen on both sides. Learning by attending to reward and punishment, by tracking what works and what does not work, seems to have been invented independently sever-

al times in evolution. If, on the other hand, it was present in the human/octopus common ancestor, it was greatly elaborated down each of the two lines.

There are also more subtle psychological similarities. Research indicates that octopuses, like us, seem to have a distinct short- and long-term memory. They seem to have something like sleep. And a 2012 study led by Jean G. Boal of Millersville University in Pennsylvania discovered that cuttlefish appear to have a form of rapid eye movement (REM) sleep, similar to the sleep in which we dream. (It is still unclear whether octopuses share this REM-like sleep.) Other similarities are even more abstract, such as recognizing individual humans. This ability makes sense if an animal is social or monogamous, but octopuses are not monogamous, have haphazard sex lives and do not seem to be very social.

Even so, there is a lesson here about the ways that smart animals handle the stuff of their world. They carve it up into objects that can be remembered and identified despite changes in how those objects present themselves. This, too, is a striking feature of the octopus mind—striking in its familiarity and similarity to how we two-legged types make sense of our world. **M**

MORE TO EXPLORE

- **Octopuses (*Eeteroctopus doffeini*) Recognize Individual Humans.** Roland C. Anderson et al. in *Journal of Applied Animal Welfare Science*, Vol. 13, No. 3, pages 261–272; 2010.
- **Octopus *vulgaris* Uses Visual Information to Determine the Location of Its Arm.** Tamar Gutnick et al. in *Current Biology*, Vol. 21, No. 6, pages 460–462; March 22, 2011.
- **Octopus Genome Holds Clues to Uncanny Intelligence.** Alison Abbott in *Nature*. Published online August 12, 2015.

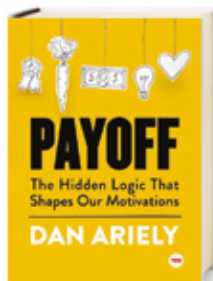
From Our Archives

- **How to Build a Robot Octopus.** Katherine Harmon Courage; *Scientific American*, October 2013.

POWER OF PURPOSE

Payoff: The Hidden Logic That Shapes Our Motivations

by Dan Ariely. Simon & Schuster/TED, 2016 (\$16.99; 120 pages)



Instead of writing this review, I'd rather be fussing with my phone or eating lunch. Luckily, Ariely's book *Payoff* provides concrete mind-hacking strategies to achieve a state of satisfying productivity. What better way to motivate myself than

by road testing its recommendations?

According to Ariely, a Duke University psychology professor, real motivation—the kind that fountains up of its own accord—is all about *meaning*. He begins his argument by impishly describing how to demolish the meaning in any task: force someone into it and then ignore the results. Even better: undo whatever they just did, ideally right in front of them. Ariely describes a hilariously cruel experiment in which participants were paid to circle pairs of identical letters on papers filled with random characters. On completion, the experimenter would immediately insert the papers into a shredder and then ask subjects if they would consider performing the same task again for even less money. Needless to say, most gave up after about five rounds.

This review may encounter a similar fate—metaphorically speaking, at least—with paper copies ultimately landing in the recycling bin and the online version consigned to the digital void. What force could counter this sense of futility? *Craft*, Ariely says. Simply seeing a task through to completion with a modicum of competence and autonomy can imbue even the most thankless labor with surprising meaning. Take assembling IKEA furniture. The process may be tedious and the results adequate at best. But in the end, it's *yours*, damn it.

If that fails, money talks—and pizza and encouragement may speak even louder. Ariely found that workers at a computer-chip factory were nearly 7 percent more productive when promised free pizza vouchers in exchange for hitting their targets. A text message from the boss saying, “Well done!” elicited similar results, but a cash bonus boosted productivity by

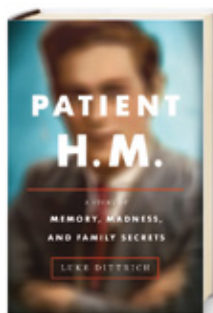
less than 5 percent. Why? The free food and feedback enhanced the personal connection between workers and managers, making the extra effort more worthwhile. *Payoff* swerves into mushier territory in its final pages, as Ariely sermonizes on capital-M meaning as the key to living a fulfilling life, not just producing more widgets. Here the book lives up to its origins in a

TED talk Ariely gave in 2012 called “What Makes Us Feel Good about Our Work?” A dense exegesis of human psychological machinery this book is not. Think of *Payoff* more like a feel-good-then-kinda-bad-then-good-again amuse-bouche for getting on with whatever it is that you don't particularly feel like doing. If you've read this far, I can confirm: it worked for me. —John Pavlus

FAILING MEMORIES

Patient H.M.: A Story of Memory, Madness, and Family Secrets

by Luke Dittrich. Random House, 2016 (\$28; 464 pages)



Henry Molaison became epileptic following a childhood head injury. His condition worsened until even extreme doses of medication could not control it, leaving him unable to live independently. In 1953, at age 27, he resorted to having a lobotomy to stop his seizures.

Using a drill, neurosurgeon William Scoville bore two holes in Henry's skull above his eyes, lifted up his frontal lobes with a long, skinny spatula and vacuumed out large portions of the temporal lobes underneath. When Henry woke up, he was no longer epileptic, but he was also no longer himself. He could not make new memories or access many old ones. He would never recall family Christmases, his first crush or what he ate for breakfast.

Henry, or H.M., as he is now best known, ultimately had a foundational influence on memory science. In *Patient H.M.*, journalist Dittrich describes how investigations of his condition helped to drive the pivotal discovery of the hippocampus and its role in semantic memories (general knowledge), which Henry retained from before his surgery, and episodic or autobiographical memories, which he lost. “Studies of Henry unexpectedly led to a second revolution: the notion that the brain contained at least two distinct and independent memory systems, one that was intact in Henry and one that was not,” Dittrich writes.

But memory science is not the book's central focus. Dittrich is more interested in ethics, largely because Scoville was his grandfather. He narrates Scoville's story and presents a comprehensive and gruesome history of lobotomy up to its heyday in the 1950s and 1960s. He also tries to dissect his grandfather's motives. How could Scoville remain confident in the lobotomy procedure, despite the overwhelming evidence that it harmed his patients? Dittrich cannot exonerate or fully understand his grandfather's actions, but he does paint them as well within the medical mores of the time.

The remainder of the book chronicles the scientists who worked with H.M. and their research, and Dittrich finds their ethics as questionable as those of the lobotomizers. Scientists at the Massachusetts Institute of Technology, led by psychologist Suzanne Corkin, put H.M. through intensive testing. In one experiment, they stretched his pain tolerance to the limit, burning him so severely with electric current that it scarred his skin, according to Dittrich's telling. H.M. remembered almost none of it.

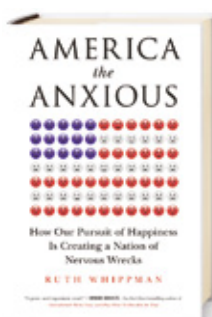
Dittrich has said that Corkin, who passed away last year, told him in recorded interviews that she shredded H.M.'s data. But since the book's release, faculty at M.I.T.'s brain and cognitive sciences department have publicly investigated and refuted that claim. “All the evidence we were able to find, from those who worked with Professor Corkin and from reviewing the actual filing cabinets filled with data from research with Henry Molaison, indicates that these records were maintained and not destroyed,” department head James DiCarlo wrote in a statement. Dittrich also alleges that Corkin was so fiercely protective of her legacy that she tried to stifle evidence that H.M. had a secondary brain lesion, found after his death. But again, M.I.T. professors responded, noting that Corkin had published descriptions of the lesion.

For all the controversy, Dittrich's account is captivating as it argues the point that science stole H.M.'s humanity, removing his memory and turning him into a professional research subject. His case and the lingering ethical questions about it help to highlight how fundamentally fragile and malleable memory really is. —Meredith Knight

HAPPINESS TRAP

America the Anxious: How Our Pursuit of Happiness Is Creating a Nation of Nervous Wrecks

by Ruth Whippman. St. Martin's Press, 2016 (\$25.99; 256 pages)



“Americans as a whole invest more time and money and emotional energy in the explicit pursuit of happiness than any other nation on earth,” writes Whippman, a British expat now living in California. But for all this effort, she adds, we are not a happy

bunch. The World Health Organization has called the U.S. one of the least happy and most anxious of all developed countries.

In *America the Anxious*, Whippman strives to get to the bottom of this paradox: Why does a nation so infatuated with happiness seem so discontented? After combing through the scientific literature, she proposes an answer: relationships. Research consistently shows that fostering

intimate bonds and close community ties makes people happier. And yet, Whippman observes, “increasingly, Americans are chasing happiness by looking inward into their own souls, rather than outward toward their friends and communities.”

We pursue solo activities, such as meditation and running, and nearly interaction-free group events, such as yoga classes and mindfulness seminars. As Whippman discovers, we have pared down our human connections to a bare minimum: the American Time Use Survey shows that the average American now spends just a few minutes a day attending or hosting social events and far less than an hour a day “doing any kind of ‘socializing and communicating’ at all.”

To research her book, Whippman embarked on a yearlong cultural immersion. She attended a “bliss-promising” self-help seminar, visited a self-proclaimed happiness evangelist’s urban

development project and even lived with a Mormon family in Utah, the happiest state in America, according to national polls. Ultimately, she writes, the more she actively pursued her own happiness, the more anxious and lonely she felt.

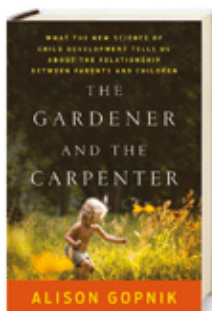
How did our desire to be happy devolve into a misguided, anxiety-provoking chase? Whippman looks to the multibillion-dollar positive psychology industry and how it influences prominent researchers. Projects focusing on happiness as a solo venture, she asserts, seem more likely to receive funding than those examining how long working hours, little vacation time, racism and inequality affect well-being.

Unfortunately, Whippman does not develop this angle in any great depth, which could have made *America the Anxious* truly significant. Her cheeky, outsider observations and self-deprecating humor make for an engaging read, but without a more probing analysis, the book ends up feeling glib. She concludes, for instance, that Americans need “to develop a vision of happiness that is inclusive and generous and socially aware.” Without specific strategies to do so, however, we are stuck observing happiness through the typical case. —Lindsey Konkel

PRO-PARENTING

The Gardener and the Carpenter: What the New Science of Child Development Tells Us about the Relationship between Parents and Children

by Alison Gopnik, Farrar, Straus and Giroux, 2016 (\$26; 320 pages)



In the mid-20th century the experience of being a parent changed dramatically. Instead of focusing on nurturing children passively, parenting became more of a professional sport, centered on active, even aggressive, efforts to ensure we turn out well-adjusted, productive adults. That parenting approach has since become pervasive in Western society—and a constant source of anxiety for new moms and dads who fret that they are never doing enough to help their children succeed.

They can relax now. In *The Gardener and the Carpenter*, Gopnik draws on pioneering research and her own experiences as a mother and grandmother to explain why this parenting model is deeply flawed. A developmental psychologist and philosopher at the University of California, Berkeley, she details the nuances of how children learn best and addresses controversial and often misunderstood subjects. She asserts, for instance, that technology does not harm children’s brain development and challenges the current schooling methods that mimic overactive parenting styles.

Gopnik’s main idea is that the more parents deliberate on how best to raise their children, the less successful they will be and the less happy and healthy their kids will become. Child development is ultimately a messy and complex process, so any attempts to shape it in a rigid way often fail spectacularly. Even when we try to explicitly teach youngsters certain facts and values, they will naturally grasp others—about the intentions and trustworthiness of adults, for example—in ways we do not really understand.

According to Gopnik, who reviews her own work and other research on brain development in this book, the way young children learn is akin to an acid trip. In early life, they absorb prodigious amounts of unfiltered information and, much like little scientists, test their ideas about how the world works through spontaneous play. Studies show that unstructured play supports children’s cognitive and social development and fosters their imagination much more than structured play does.

The take-home message here is that there is no right way to raise children, and as a result, Gopnik offers few practical tips on how to be a better parent. She does provide more general advice, however: rather than acting like goal-directed “carpenters” who aim to structure their progeny into some predetermined form—say, a doctor like their grandfather—caregivers should be more like gardeners who cultivate a rich and loving environment in which children are free to flourish and become whoever they really are.

Gopnik’s deep expertise and her compelling writing make this book an informative and entertaining account of the latest scientific research on childhood development—one that will undoubtedly bring comfort to many who worry whether their parenting skills are up to scratch. —Moheb Costandi



When do children start making long-term memories?

—Red Smucker-Green Atlanta



Dima Amso, an associate professor in the department of cognitive, linguistic and psychological sciences at Brown University, answers:

The early years of parenthood involve so many rewarding firsts—when your infant cracks a toothless grin, when he crawls and later walks, and, of course, when he utters a real, nonbabble word. A mother once told me she found it sad that if she were to pass away suddenly, her toddler wouldn't remember her or these exciting years. It is true that most of us don't remember much, if anything, from our infancy. So at what point do children start making long-term memories?

I must first explain the different types of memory we possess. As I type this, I am using procedural memory—

a form of motor memory in which my fingers just know how to type. In contrast, declarative memories represent two types of long-term recall—semantic and episodic. Semantic memory allows us to remember general facts—for

example, that Alfred Hitchcock directed the film *Vertigo*; episodic memory encompasses our ability to recall personal experiences or facts—that *Vertigo* is my favorite film. Episodic memories are most relevant for understanding our childhood recollections.

Making an episodic memory requires binding together different details of an event—when it happened and where, how we felt and who was there—and retrieving that information later. The processes involve the medial temporal lobes, most notably the hippocampus, and portions of the parietal and prefrontal cortices, which are very important in memory retrieval. Imaging

How do connectomes contribute to human cognition?

—Paul Vander Griendt via e-mail



Alexander Fornito, an associate professor at the Monash Institute of Cognitive and Clinical Neurosciences in Melbourne, Australia, responds:

The human brain is an extraordinarily complex network, comprising an estimated 86 billion neurons connected by 100 trillion synapses. A connectome is a comprehensive map of these links—a wiring diagram of the brain.

With current technology, it is not possible to map a network of this size at the level of every neuron and synapse. Instead researchers use techniques such as magnetic resonance imaging to map connections between areas of the human brain that span several millimeters and contain many thousands of neurons.

At this macroscopic scale, each area comprises a specialized population of neurons that work together to perform

particular functions that contribute to cognition. For example, different parts of your visual cortex contain cells that process specific types of information, such as the orientation of a line and the direction in which it moves. Separate brain regions process information from your other senses, such as sound, smell and touch, and other areas control your movements, regulate your emotional responses, and so on.

These specialized functions are not processed in isolation but are integrated to provide a unitary and coherent experience of the world. This integration is hypothesized to occur when different populations of cells synchronize their activity. The fiber bundles that connect different parts of the brain—the wires of the connectome—provide the substrate for this communication. These connections ensure that brain activity unfolds through time as a rhythmic symphony rather than a disordered cacophony.

If brain wiring helps to coordinate neuronal activity, do people with different wiring patterns show differences in cognitive abilities? Some studies have shown that those with patterns of brain

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A six-year-old can remember events from before her first birthday, but by adolescence, she has probably forgotten that celebration.

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studies often show that the same regions that encode an episode—for example, the visual cortex for vivid visual experiences—are active when we recall that memory, allowing for a kind of “mental time travel” or replay of the event.

Some evidence suggests that young children do have episodic memories of their infancy but lose them later. A six-year-old, for instance, can remember events from before her first birthday, but by adolescence, she has probably forgotten that celebration. In other words, young children can likely make long-term-like memories, but these memories typically fade after a certain age or stage of brain development. Memories made in

later childhood and beyond are more likely to stick because the young brain, especially the hippocampus and the frontoparietal regions, undergoes important developmental changes that improve our ability to bind, store and recall events.

There is good news, however, for that mother and any other parent who worries that their toddler will not remember their special early years together. A memory is essentially a unit of experience, and every experience shapes the brain in meaningful ways. Specific memories may be forgotten, but because those memories form the fabric of our identities, knowledge and experiences, they are never truly or completely gone.

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Functional networks in the brain emerge and dissolve like eddies in a stream, promoting the formation of new connections or the pruning of unused ones.
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wiring that are particularly efficient at integrating information perform better on tests of general intelligence, whereas those diagnosed with disorders that affect cognition, such as schizophrenia, often have less efficient wiring patterns. Damage to regions of the brain that are highly connected to others may result in especially severe cognitive impairments. These findings indicate that patterns of brain-network wiring do indeed contribute to cognition.

Brain structure does not completely determine brain function, however. If this were true, our brains would be trapped in an endless cycle of repetitive activity, leaving us unable to learn or adapt to novel situations. Instead the connectome provides a scaffold on which different cell populations modulate and coordinate their activity to form transient and diverse coalitions.

These functional networks emerge and dissolve like eddies in a stream, promoting the formation of new connections or the pruning of unused ones. In this way, brain-network structure and function form a kind of symbiosis, with cognition depending both on the precise way in which the connectome is wired and on the dynamic patterns of neuronal activity that unfold within the network. **M**

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

**Send it to
 MindEditors@sciam.com**

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1 CANDLE COUNT

Casey and his mom are both celebrating birthdays and turning ages that are perfect squares. In four years, Casey's age will be exactly half his mother's age. How old are they now?

2 WHAT'S NEXT?

What number is missing from this sequence?

1 3 4 3 9 5 16 4 25 _ 36 3

3 WORD WATCH

What do the following words have in common?

- Awning**
- East**
- Earned**

4 RESCUE LOG

Firefighters Dean and Henry rescued a number of cats from trees in one week. Henry rescued twice as many cats as Dean. The total number of cats rescued is a perfect square. Neither rescued more than one cat a day. How many cats did each man rescue?

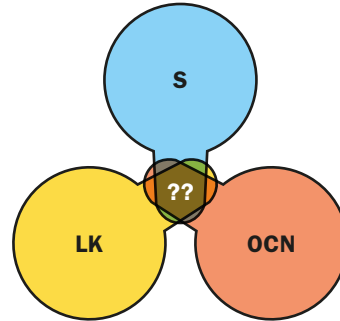
5 SOUNDS OF SCIENCE

The following is a clue for what science-related word?

4N6

6 FINDING VOWELS

The same two vowels have been plucked from these three related words. Can you put the words back together?



7 SCHEDULING PROBLEM

If JT works one shift every second day, Laura works once every third day, and Aditya works every fifth day, how often do all three colleagues work together?

8 TAKING SHAPES

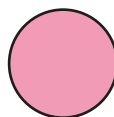
Using the first three shapes and values as a guide, find the value that corresponds to the last shape.



24



40



01



??

9 GREEN FIGURES

A recycling dumpster holds a maximum of 27 bags of recycled materials. An apartment building puts out about nine bags of recycling every month. Two dumpsters could service how many apartment buildings in one month?

10 MISSING DIGITS

What number should replace the question mark below?

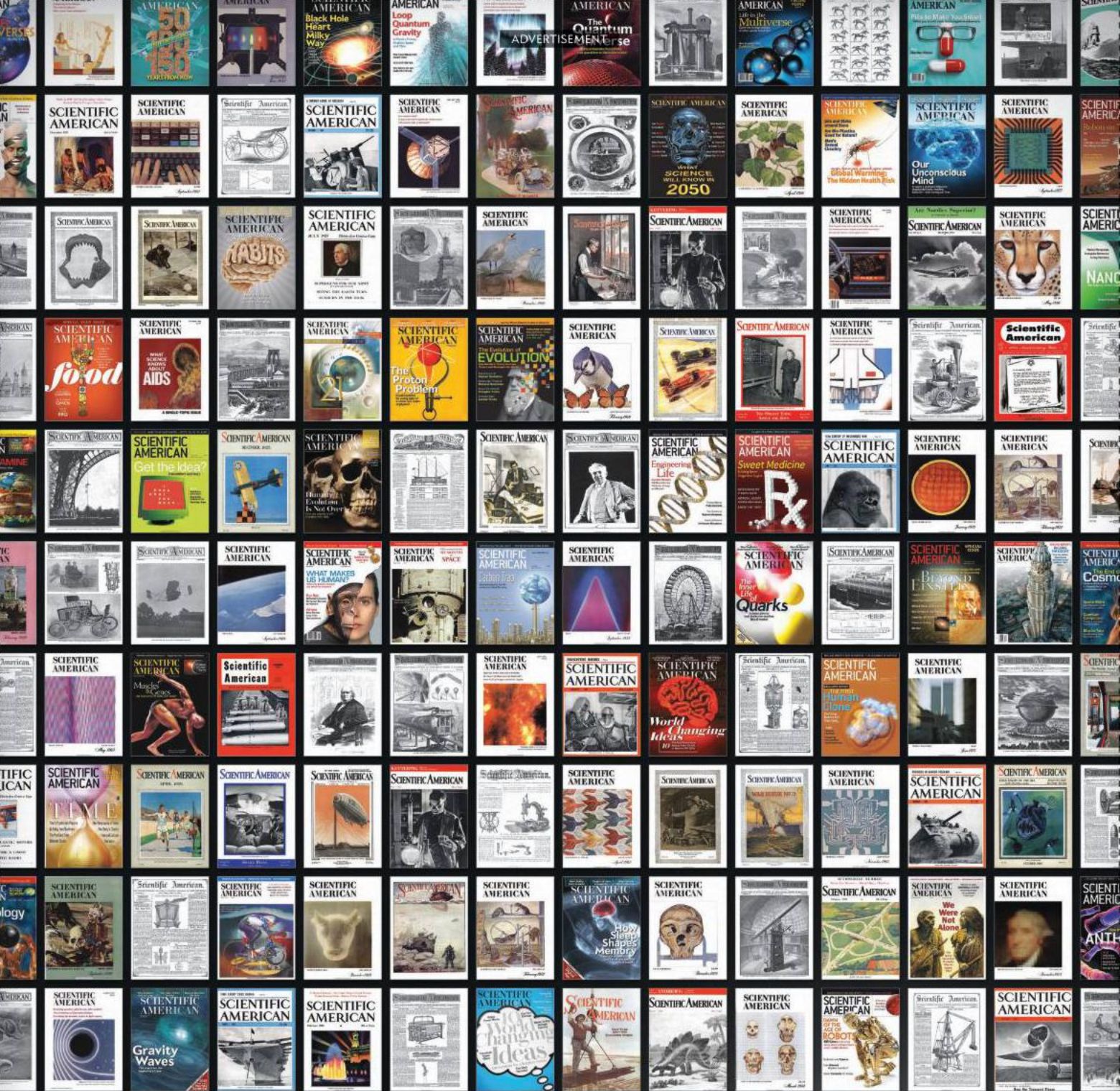
- 24 ... 8.5**
- 35 ... 15.6**
- 18 ... 8.125**
- 68 ... ?**

Answers

9. Six.
10. 48.75. The answers are made by multiplying the digits (48), then dividing them (0.75) and writing those answers together.
11. The number of straight lines, followed by the number of curved lines and one curved line.
12. Each number displays $(2 \times 3 \times 5)$.
13. Every 30th day

3. Each word can become a new word by adding "Y": yawning, yeast and yeared.
4. Henry rescued six cats, and Dean rescued three.
5. Forensics (four N six), and LAKE.
6. A and E: SEA, OCEAN

1. 16 and 36.
2. 4. The sequence shows each perfect square up to 36, followed by the number of letters in the word for its square root—in this case, "five."
3. Each word can become a new word by adding "Y": yawning, yeast and yeared.
4. Henry rescued six cats, and Dean rescued three.
5. Forensics (four N six), and LAKE.
6. A and E: SEA, OCEAN



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WINTER BLUES

BY DWAYNE GODWIN & JORGE CHAM

THE WINTER MONTHS BRING COLD AND GLOOM.



AND FOR MANY, A SERIOUS CASE OF THE WINTER BLUES.

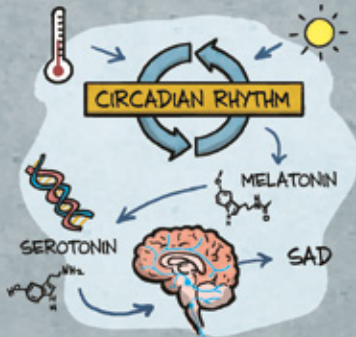
SEASONAL AFFECTIVE DISORDER (SAD) IS A DIAGNOSED TYPE OF DEPRESSION THAT IS TIED TO THE CHANGING OF THE SEASONS.

SAD

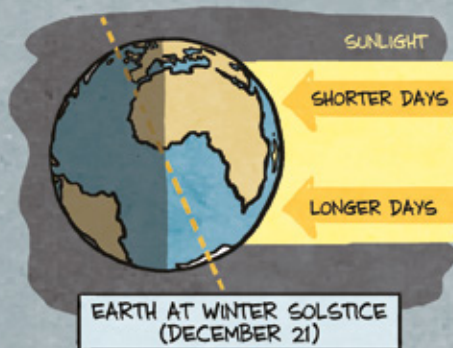
SAD MAY BE SHAPED BY DIFFERENT FACTORS, INCLUDING CHANGES IN YOUR BIOLOGICAL RHYTHMS, YOUR APPETITE AND HOW YOU REACT TO LIGHT—EACH OF WHICH INVOLVES MANY GENES.



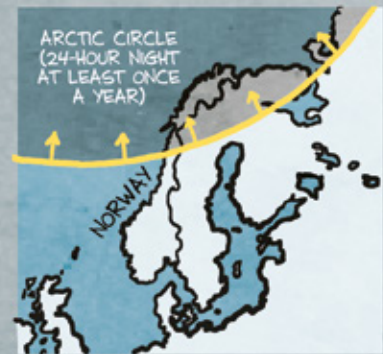
FOR EXAMPLE, STUDIES IN MICE SUGGEST THAT HORMONES IN THE CIRCADIAN CYCLE CAN ALTER THE GENE EXPRESSION OF NEUROTRANSMITTERS THAT ARE LINKED TO DEPRESSION.



SAD SHOULD BE MORE PREVALENT IN NORTHERN AREAS, WHERE THE WINTERS ARE GLOOMIER—BUT SOME STUDIES HAVE REPORTED LITTLE RELATION OF DEPRESSION TO LATITUDE.



FOR INSTANCE, NORTHERN REGIONS SUCH AS NORWAY DON'T SHOW A HIGHER INCIDENCE OF DEPRESSION SYMPTOMS.



FOR THOSE WHO DO SUFFER, PHOTOTHERAPY WITH A BRIGHT, HIGH-QUALITY LIGHT BOX CAN OFTEN BRING RELIEF.



ANTIDEPRESSANTS CAN ALSO BE HELPFUL, AND TALK THERAPIES CAN ENHANCE RECOVERY BY HELPING PATIENTS PROCESS NEGATIVE EMOTIONS.



SOME STUDIES HAVE SHOWN BOTH TREATMENTS TO BE AS EFFECTIVE AS LIGHT THERAPY.

SO DON'T LET THE WINTER GLOOM GET YOU DOWN.



SPRING INTO ACTION, GET HELP AND WATCH YOUR SPIRITS BLOOM.

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

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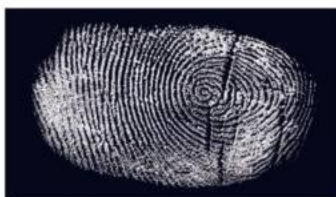
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- Black Holes and Gravitational Waves

SPEAKERS:

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- Elizabeth Murray, Ph.D.
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