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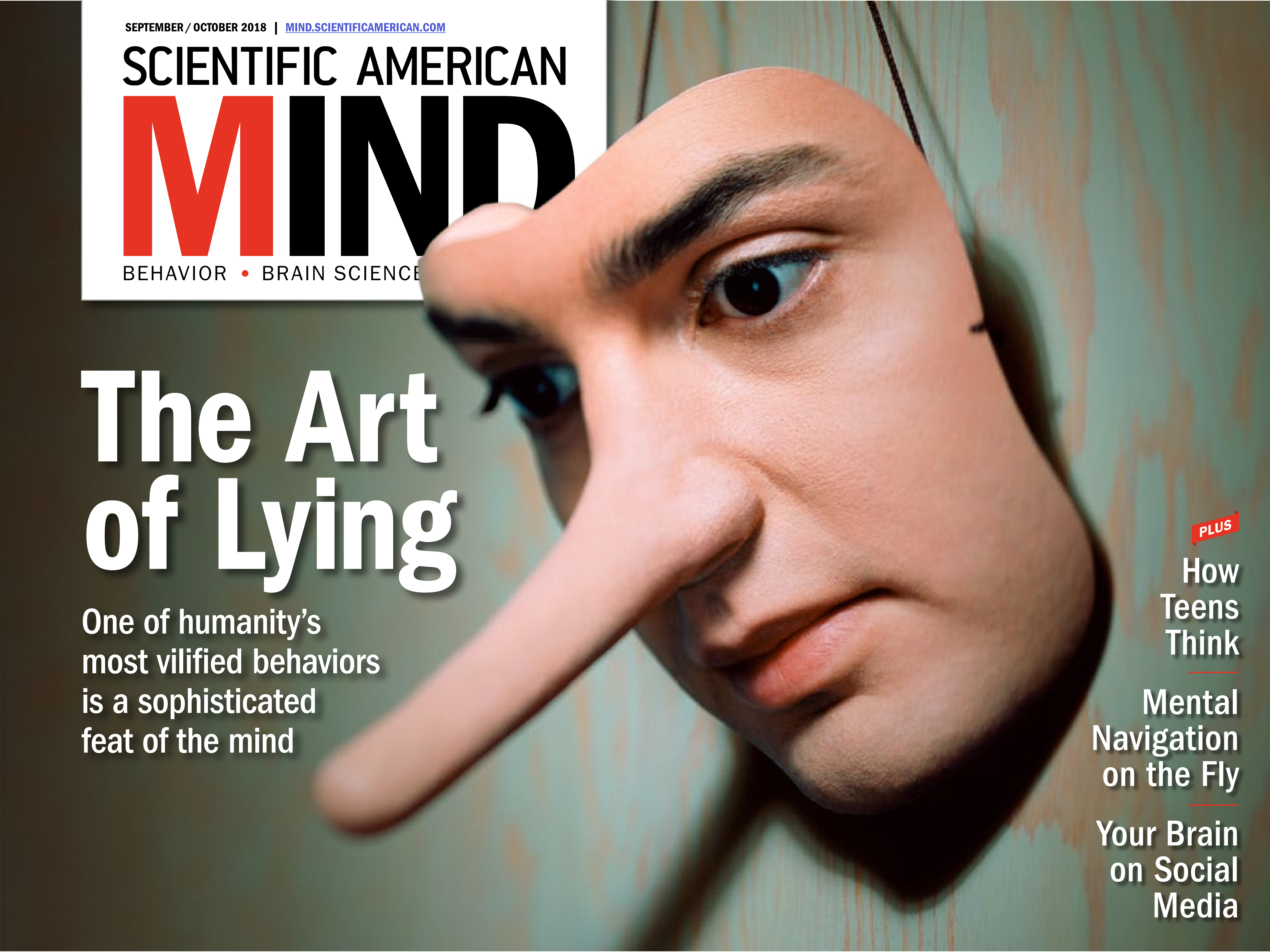


The Art of Lying

One of humanity's most vilified behaviors is a sophisticated feat of the mind

PLUS

How Teens Think

Mental Navigation on the Fly

Your Brain on Social Media

FROM THE EDITOR

A Necessary Evil

On November 17, 1973, President Richard M. Nixon infamously declared on television "I am not a crook" when questioned about his role in what would later be called the Watergate scandal. Diligent work by investigative reporters soon after revealed the falsity in his words. In this issue's cover feature, Theodor Schaarschmidt tells the story of another politician—a high-ranking policy official in Europe--who came down with a strange problem: on some occasions of telling a lie, he would pass out and convulse on the floor, truly perplexing his neurologist. However impossible (or fantastical), I have never more wished that cases of Pinocchio nose would break out among our politicians. But, alas, telltale signs of lying would likely trigger the breakdown of society. Imagine disclosing to each person you interact with today the real thoughts in your head. Yes, that would become messy quickly. Lying seems to be a requirement of society, but it is also an art form, one that takes effort and special brain functionality (read more in "The Art of Lying").

Elsewhere in this issue Kerri Smith details the fascinating research on how adolescents embrace risk-taking—good news, parents: that same rebellious behavior can have many positive effects (see "Sex, Drugs and Self-Control"). And in "Bat Man," Alison Abbott describes the work of neuroscientist Nachum Ulanovsky, who has constructed a "flight tunnel" to study the navigating brains of bats in real time. Enjoy and let us know what you think!

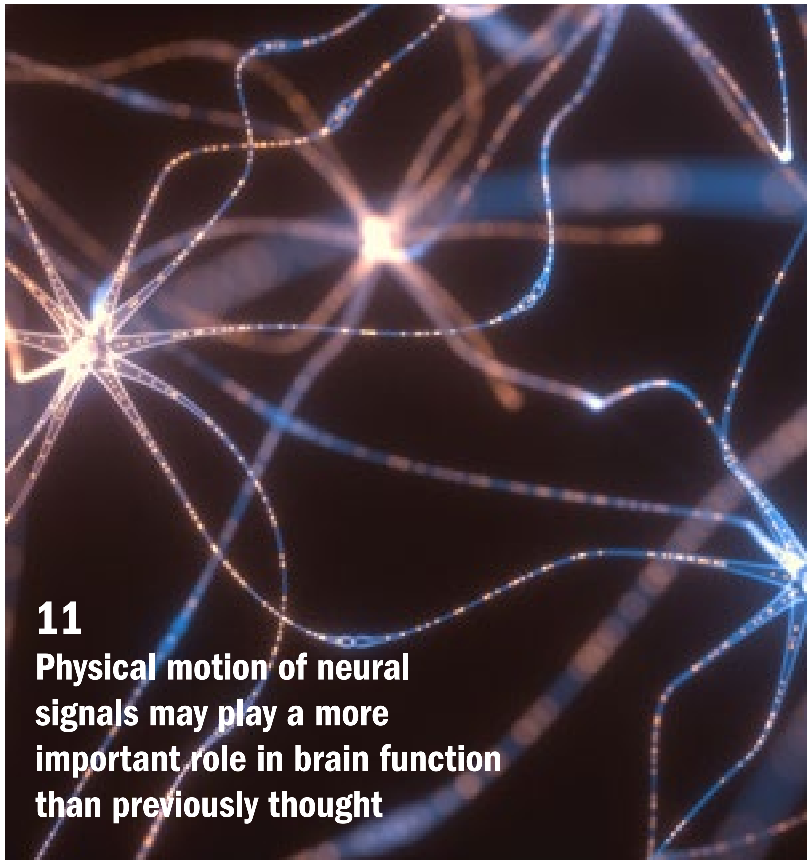
Andrea Gawrylewski
Collections Editor, editors@sciam.com

COVER: HUGH KRETSCHMER; THIS PAGE: LIZ TORMES

CONTENTS

5
Research could help explain why people think things are getting worse when they are actually getting better

8
European nations see biggest increases in use of stimulants such as Ritalin by people seeking brain-boosting effects



11
Physical motion of neural signals may play a more important role in brain function than previously thought

News

CONTENTS

DAVID VAAKNIN *FOR NATURE*

33
How does the brain know where it is? Nachum Ulanovsky hopes his flying friends can help him find the answer

PERY BURGE *GETTY IMAGES*

41
Psychedelics have psychological and spiritual benefits, as a new best seller claims, but they're far from a panacea

CHRISTIN LOLA *GETTY IMAGES*

48
How to handle grief after a pet's death—and why we all need to change our attitudes about it

Features

Opinion

JO McRYAN GETTY IMAGES

NEWS

The Despondent Mind: Are Our Brains Wired for Doom and Gloom?

Research could help explain why people think things are getting worse when they are actually getting better

If it seems the state of the world is on an endless downward trajectory these days, take heart. Things might not be quite as bad as you think. New research, published in June in *Science*, suggests that as social problems such as extreme poverty or violence become less prevalent, people may be prone to perceive that they linger—and are perhaps even getting worse.

Led by psychologist Daniel Gilbert at Harvard University, the researchers found people readily and unconsciously change how they define certain concepts—ranging from specific colors to unethical behavior—based on how frequently they run into them. "On almost every dimension, the world is getting better. And yet when people are asked, they consistently say it's not getting better, and in fact it's getting worse," Gilbert says. "As we solve problems, we also unknowingly expand our definitions of what counts as them."

Concept expansion itself is not a new observation. In 2016 social psychologist Nicholas Haslam at the University of Melbourne in Australia introduced the term "concept creep" to describe the broadening of modern psychological terminology—especially negative examples such as abuse, bullying, trauma, mental disorder, addiction and prejudice—to include cases previously judged benign or inoffensive.

> **"As we solve problems, we also unknowingly expand our definitions of what counts as them." —Daniel Gilbert**

In some cases, the expansion of concepts such as aggression (and more recently, "microaggressions") in the public consciousness has sparked heated debate; some critics argue these shifts reflect political correctness run amok, whereas others claim they signal growing social awareness. Gilbert is emphatically agnostic on the issue. "Expanding a concept isn't necessarily good or bad," he says. "Science doesn't weigh in on whether it's a good or bad thing." He and others are simply interested in understanding how the phenomenon happens.

A number of factors likely contribute to these changes, among them political, social or economic forces. But the latest study highlights another intriguing player. "This is the first time someone has actually said there's a cognitive mechanism that could account for that," Haslam says.

In one of its experiments Gilbert's team showed volunteers a series of 1,000 dots, ranging in color between very purple and very blue. Participants had to judge whether each dot was blue or not. Partway through the test, researchers began showing fewer blue dots (and more purple or purplish dots) to some participants. By the end of the experiment, these study participants were more likely to say "blue" to hues in the middle of the spectrum, including some dots they had previously seen and judged "not blue."

The change was involuntary—it even occurred when volunteers were warned the frequency of blue dots would decrease. Instructing participants to maintain consistent responses did not eliminate the shift, nor did offering monetary bonuses for the most consistent performers. The effect worked both ways: Reversing the experiment and increasing the frequency of blue dots made participants less likely to call dots in the middle of the color range blue (in other words, their concept of "blue" had contracted).

Next, the researchers moved on to more complex concepts. They showed participants a series of computer-generated faces that had been independently rated on a continuum from very nonthreatening to very threatening. Those in the study had to assess whether a given face was a threat or not. Mid-experiment, researchers began showing fewer threatening faces to some participants. By the end of the session, these people had grown more likely to judge relatively innocuous faces as threats.

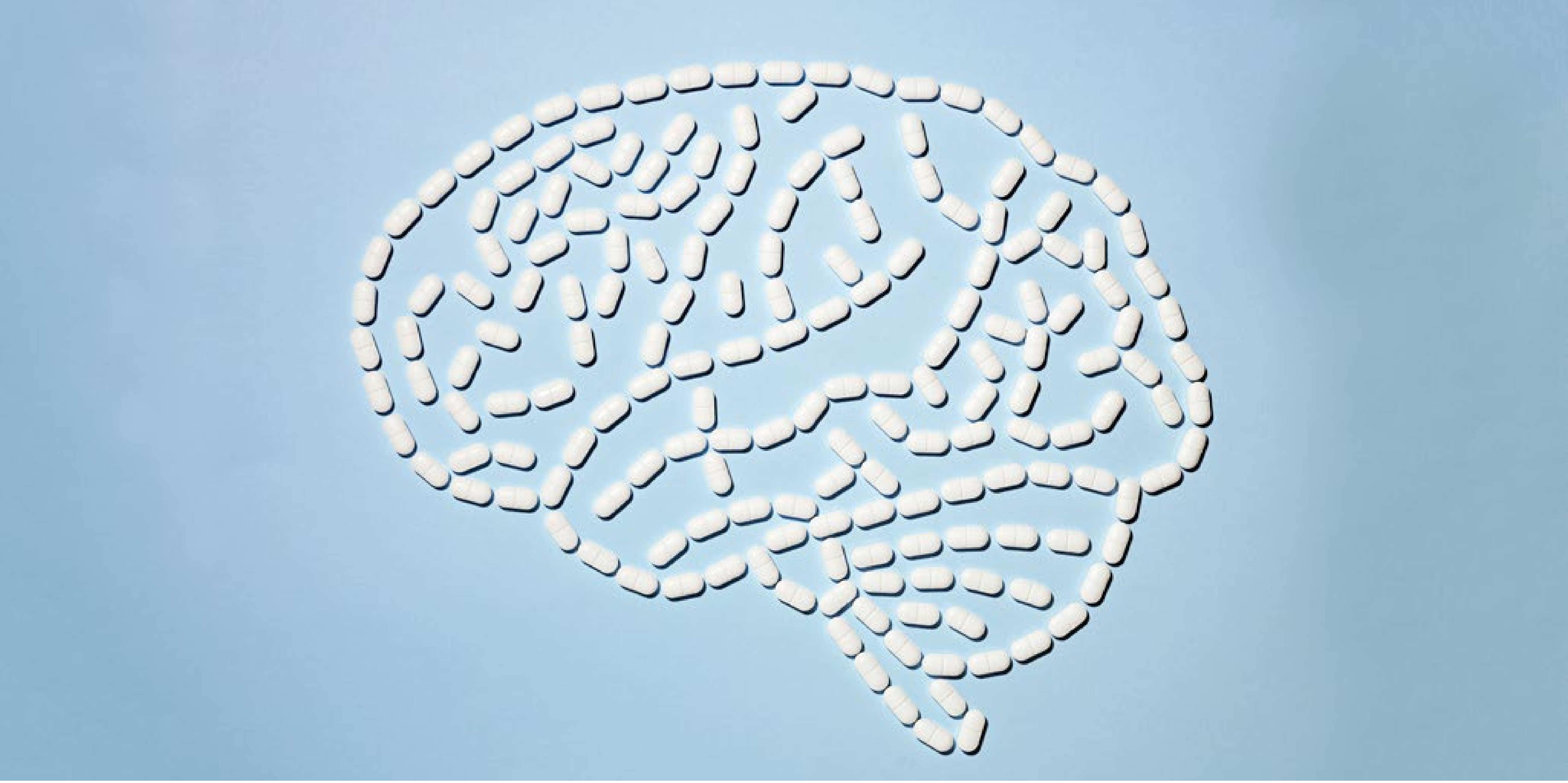
Finally, Gilbert's team prepared hundreds of mock research proposals, which were designed—and verified by independent raters—to range from ethical to ambiguous to unethical. (An example of an unethical proposal: "Participants will be asked to lick a frozen piece of human fecal

"The challenge will be to see the extent to which it generalizes outside the lab to the real world." –Scott Lilienfeld

matter. Afterwards, they will be given mouthwash. The amount of mouthwash used will be measured.") Volunteers in Gilbert's study were asked to play the role of an institutional review board, which oversees the ethics of university research projects. They had to either approve or reject a series of these proposals. Once again, when researchers began showing fewer "unethical" proposals to some of the participants, they shifted to rejecting more "ambiguous" proposals than they did earlier in the experiment. "It's a very creative, provocative study," says Scott Lilienfeld, professor of psychology at Emory University. He notes the study's strength lies in showing the same effect across a range of situations—from simple perceptual problems to ethical judgments. "The challenge will be to see the extent to which it generalizes outside the lab to the real world," says Lilienfeld, who did not take part in the work.

Going forward, Gilbert's team is working on computational models that might point to the thought processes that lead people to change their concepts based on how often they come upon instances of them. For those looking to glean practical lessons from their initial results, Gilbert says, "We're prone to never see the end of a problem. Before we try to solve it, we should try to say what would count as having solved it." But even he acknowledges that for some complex, real-world issues, these measures will be extremely hard to define.

—HELEN SHEN



NEWS

Use of “Smart Drugs” on the Rise

European nations see biggest increases in use of stimulants such as Ritalin by people seeking brain-boosting effects

TS PHOTOGRAPHY *GETTY IMAGES*

The use of drugs by people hoping to boost mental performance is rising worldwide, finds the largest ever study of the trend. In a survey of tens of thousands of people, 14 percent reported using stimulants at least once in the preceding 12 months in 2017, up from 5 percent in 2015.

The nonmedical use of substances—often dubbed smart drugs—to increase memory or concentration is known as pharmacological cognitive enhancement (PCE), and it rose in all 15 nations included in the survey. The study looked at prescription medications such as Adderall and Ritalin—prescribed medically to treat attention deficit hyperactivity disorder (ADHD)—as well as the sleep-disorder medication modafinil and illegal stimulants such as cocaine.

The work, published in the *International Journal of Drug Policy* in June, is based on the Global Drug Survey—an annual, anonymous online questionnaire about drug use worldwide. The survey had 79,640 respondents in 2015 and 29,758 in 2017.

U.S. respondents reported the highest rate of use: in 2017, nearly 30 percent said they had used drugs for PCE at least once in the preceding 12 months, up from 20 percent in 2015.

But the largest increases were in Europe: use in France rose from 3 percent in 2015 to 16 percent in 2017; and from 5 percent to 23 percent in the United Kingdom. An informal reader survey by *Nature* in 2008 found that one in five respondents had used drugs to boost concentration or memory.

The latest analysis is impressive in its size, says Barbara Sahakian, a neuroscientist at the University of Cambridge, who was not involved in the work. There is an increasing "lifestyle use" of cognitive-enhancing drugs by healthy people, which raises ethical concerns, she says.

Cultural factors, the prevalence of ADHD diagnoses and availability all influence which drugs are used for PCE and the rate of use, says Larissa Maier, a psychologist at the University of California, San Francisco, who led the study.

In the United States, where ADHD diagnoses are high and medication is a common treatment, 22 percent of respondents said they had used amphetamine-combination drugs such as Adderall for PCE. Those drugs are not approved in the European Union, where methylphenidate—sold under various trade names, including Ritalin—is more commonly used.

The use of drugs by people hoping to boost mental performance is rising worldwide.

The study suggests that the spread of U.S.-style practices in ADHD treatment is driving the trend and making drugs more available: countries with higher rates of ADHD diagnoses, such as the United States, Canada and Australia, have higher rates of nonmedical prescription-drug use for cognitive enhancement.

"The increased diagnoses of ADHD and their prescription drug use are creating a substantial population of young pharmacologically medicated persons whose underlying problems may very likely be located in their social world," says Steven

Rose, a neuroscientist at the Open University in Milton Keynes.

Nearly half (48 percent) of people said they obtained the drugs through friends; 10 percent bought them from a dealer or over the Internet; 6 percent obtained them from a family member; and 4 percent said that they had their own prescriptions.

Debate continues over whether the nonmedical use of prescription drugs boosts brain performance. Data suggest that some people benefit from certain drugs in specific situations—for example, surgeons using modafinil—but larger population-wide studies report lesser gains and conflicting results.

Maier notes that respondents to the Global Drug Survey are more likely than the general population to be interested in drug use, which could bias results. But she says that similar rates of nonmedical use of smart drugs are seen in studies of the general population, suggesting that the findings are robust.

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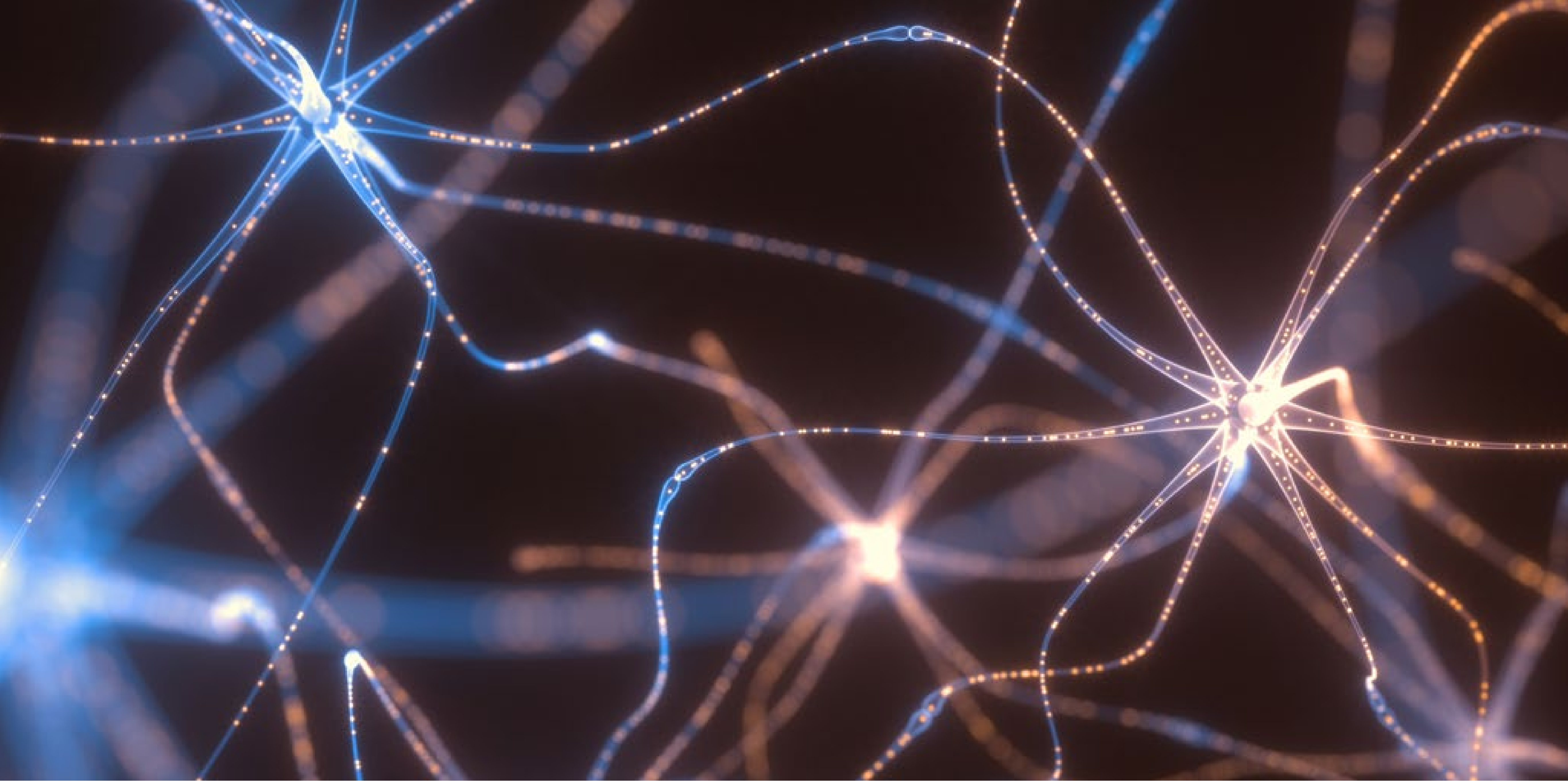
—ARRAN FROOD



NEWS

“Traveling” Brain Waves May Be Critical for Cognition

Physical motion of neural signals may play a more important role in brain function than previously thought

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The electrical oscillations we call brain waves have intrigued scientists and the public for more than a century. But their function—and even whether they have one, rather than just reflecting brain activity like an engine's hum—is still debated. Many neuroscientists have assumed that if brain waves do anything, it is by oscillating in synchrony in different locations. Yet a growing body of research suggests many brain waves are actually "traveling waves" that physically move through the brain like waves on the sea.

Now a new study from a team at Columbia University led by neuroscientist Joshua Jacobs suggests traveling waves are widespread in the human cortex—the seat of higher cognitive functions—and that they become more organized depending on how well the brain is performing a task. This shows the waves are relevant to behavior, bolstering previous research suggesting they are an important but overlooked brain mechanism that contributes to memory, perception, attention and even consciousness.

Scientists have proposed numerous possible roles for brain waves.

Brain waves were first discovered using electroencephalogram (EEG) techniques, which involve placing electrodes on the scalp. Researchers have noted activity over a range of different frequencies, from delta (0.5 to 4 hertz) through to gamma (25 to 140 Hz) waves. The slowest occur during deep sleep, with increasing frequency associated with increasing levels of consciousness and concentration. Interpreting EEG data is difficult due to their poor ability to pinpoint the location of activity, and the fact that passage through the head blurs the signals. The new study, published in June in *Neuron*, used a more recent technique called electrocorticography (ECoG). This involves placing electrode arrays directly on the brain's surface, minimizing distortions and vastly improving spatial resolution.

Scientists have proposed numerous possible roles for brain waves. A leading hypothesis holds that synchronous oscillations serve to "bind" information in different locations together as pertaining to the same "thing," such as different features of a visual object (shape, color, movement, et cetera). A related idea is they facilitate the transfer of information among regions. But such hypotheses require brain waves to be synchronous, producing "standing" waves (analogous to two people swinging a jump rope up and down) rather than traveling waves (as in a crowd doing "the wave" at a sports event). This is important because traveling waves have different properties that could, for example, represent information about the past states of other brain locations. The fact they physically propagate through the brain like sound through air makes them a potential mechanism for moving information from one place to another.

These ideas have been around for decades, but the majority of neuroscientists have paid little attention. One likely reason is that until recently most previous reports of traveling waves—although there are exceptions—have merely described the waves without establishing their significance. "If you ask the average systems neuroscientist, they'll say it's an epiphenomenon [like an engine's hum]," says computational neuroscientist Terry Sejnowski of the Salk Institute for Biological Studies, who was not involved in the new study. "And since it has never been directly connected to any behavior or function, it's not something that's important."

The tools researchers use may also have played a part. Today's mainstream neuroscience has its roots in studying the behavior of neurons one at a time using needlelike microelectrodes. Pioneering researchers in this area noticed the timing of when a neuron fired varied from one trial of an experiment to another. They concluded this timing must not be important and began combining responses from multiple trials to produce an average "firing rate." This became the standard way to quantify neural activity, but the variability may result from where neurons are in oscillation cycles, so the practice ignores the timing information needed to reveal traveling waves. "The conceptual framework grew out of what a single neuron is doing by itself," Sejnowski says, but "the brain works through populations of neurons interacting with each other." Because traveling waves comprise the activity of many neurons spread across the brain, they are invisible to single-neuron techniques. But over the last decade new technologies have appeared that allow many neurons to be monitored simultaneously. "This has given us a very different picture," Sejnowski says. "For the first time we have the tools and techniques to see what's really going on—but it's going to take a generation before it's accepted by the established neuroscience community."

Confirming the importance of traveling waves creates new horizons in neuroscience.

Optical methods, like voltage-sensitive dyes, allow researchers to visualize electrical changes in thousands of neurons simultaneously but cannot be used in humans because of the risks they pose. ECoG, however, is commonly used in epilepsy patients to investigate seizures. So the researchers behind the new study recruited 77 epilepsy patients with implanted ECoG arrays and went looking for traveling waves. They first looked for clusters of electrodes displaying oscillations at the same frequency. Nearly two thirds of all electrodes were part of such clusters, which were present in 96 percent of patients (at frequencies from 2-15 Hz, spanning the theta band at 4-8 Hz and alpha band at 8-12 Hz). The researchers next assessed which clusters represented bona fide traveling waves by analyzing the timing of the oscillations. If consecutive oscillations are part of a traveling wave, each will be slightly delayed or advanced, depending on direction of travel. (Think of how people in a crowd wave follow one another with a slight delay.) Two thirds of the clusters detected were traveling waves moving from the rear to the front of the cortex. These involved nearly half of all electrodes and occurred in all lobes and both hemispheres of patients' brains.

The team next gave participants a working-memory task and found traveling waves in their frontal and temporal lobes became more organized half a second after people were prompted to recall information. The waves changed from moving in various directions to mostly moving in concert. Importantly, the extent to which they did this varied with how quickly participants responded. "More consistent waves correspond to better task performance," Jacobs says. "This suggests a new way to measure brain activity to understand cognition, which can perhaps give rise to new, improved brain–computer interfaces." (BCIs are devices that connect a human brain to a machine that performs some task, like moving a prosthetic limb.)

These findings should help dispel some researchers' lingering doubts about the importance of such waves. "The article is a strong contribution to the study of cortical traveling waves, adding to previous work on their role in human cognition," says psychologist David Alexander of the University of Leuven in Belgium who did not take part in the work. "This really will put to rest any worries that the waves are an artifact of blurring of signal passing through the skull." He also says the authors make unjustified claims about the novelty of the findings and fail to acknowledge some previous research, however. "Previous work on traveling waves has shown they are evoked during working memory tasks," he says, pointing to a 2002 EEG study that found the timing of a reversal in direction of theta waves correlated with memory performance. Interestingly, an EEG study Alexander himself published in 2009 found fewer waves moving from the front to the back of the head during a working-memory task in people who had experienced their first episode of schizophrenia, compared with healthy individuals, suggesting differences in traveling wave behavior can be related to psychiatric symptoms. He also claims the methods the team used to assess traveling waves are similar to those he used in a 2016 study. "Alexander's work is really interesting, but it's not clear his findings involve the same signals as our paper," Jacobs notes. "He reported patterns that literally involve the entire brain, whereas our findings were limited to particular regions." Jacobs also points to differences in recording techniques and the nature of recorded signals.

Confirming the importance of traveling waves creates new horizons in neuroscience. "Finding that such a wide range of oscillations are traveling waves shows that they involve coordinating activity across different brain regions," Jacobs says. "This opens key new areas of research, such as understanding what exactly this coordination consists of." He thinks the waves propagate information, at least in the context of the current study.

Another idea holds that waves, by repeatedly moving across patches of cortex, modulate the sensitivity of neurons so as to sweep a "searchlight" of attention across, say, the brain's visual-processing area. "The concept of a traveling wave is closely tied up with the issue of how you maintain the cortex in the sweet spot where it's maximally sensitive to other inputs and able to function optimally," Sejnowski says. Interest in traveling waves will undoubtedly continue to increase. "What you're seeing right now is a transformation from one conceptual framework to a completely new framework," he adds. "It's a paradigm shift."

—SIMON MAKIN

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NEWS

Early Life Experience: It's in Your DNA

Surprising study suggests experiences while young cause the brain to experience changes to the genome

We normally think that every cell in our body contains the same genome, the complete set of genetic information that makes up the biological core of our individuality. There are exceptions where the body contains cells that are genetically different. This happens in cancers, of course, which arise when mutations create genetically distinct cells. What most people do not realize, however, is that the brain has remarkable genetic diversity, with some studies suggesting there may be hundreds of mutations in each nerve cell. In the developing brain, mutations and other genetic changes that occur while brain cells divide are passed down to a cluster of daughter cells. As a result, the adult brain is composed of a mosaic of genetically distinct cell clusters.

We know that the activity and organization of the brain changes in response to experience. Memories and learning are reflected in the number and strength of connections between nerve cells. We also know that the brain is genetically mosaic, but a new study makes a remarkable connection between experience and the genetic diversity of the brain. It suggests that experience can change the DNA sequence of the genome contained in brain cells. This is a fundamentally new and unexplored way in which experience can alter the brain. It is of great scientific interest because it reveals the brain to be pliable, to its genetic core, in response to the world.

The genome is the molecular signature of identity. The sequence of DNA contained in our genomes distinguishes each of us as unique individuals, and changes in that sequence are relatively rare. Genomic changes typically arise from rare errors during cell replication, or from exposure to carcinogens or radiation. Here, experience has an equally powerful capacity to change the genome, but only in cells of the brain. The care that a newborn receives in early life can have profound effects on psychological and intellectual growth. Attentive nurturing, feeding and grooming can reduce stress and anxiety and enhance psychological well-being. On the other hand, indifference can lead to increased anxiety and impaired psychological adjustment. This study reveals that one way the quality of early care could cause lifelong changes in behavior is by changing the brain's genetic nature.

In this study researchers identified natural differences in the quality and abundance of maternal care provided by mice based upon measures of time they spent grooming and nursing their pups. They identified groups of animals that provided either high or low maternal care. They then examined brains of their pups for differences in markers of genomic change.

Many of the differences in the genomes of nerve cells are due to the presence of mobile genetic elements called retrotransposons. These are stretches of DNA that can be copied and, as the name suggests *transposed* or incorporated into other areas of the genome. This study measured the accumulation of these mobile genetic elements in the brain as a consequence of maternal care. Mobile genetic elements accumulated in specific regions of the brains of mouse pups if the pups had poor maternal care. If a pup was born to a mother animal that provided low maternal care but raised by a mother animal that provided high maternal care, that accumulation of mobile genetic elements was eliminated. This supported the idea that the accumulation of genetic elements was due to the care provided by the mothers rather than some inherited difference. Most of the excess was found in the hippocampus, a region of the brain involved in memory, but not in other regions of the brain, nor in a completely different organ like the heart, suggesting a very specific impact on brain mosaicism.

The authors also report that the changes in levels of mobile genetic elements might in turn be mediated by a modification to the genomic DNA known as methylation. Methylation is not itself a change in the DNA sequence, but it can alter when and how DNA sequences are read and utilized by the cell. Pups raised with poor maternal care had decreased methylation of key regulatory sequences in the mobile genetic elements, which in turn led to increased numbers of these elements and increases in their activity.

There are important implications here. The augmented genomic variability among nerve cells may be beneficial to an individual by diversifying their behavioral repertoire. On the other hand, it may genetically predispose an individual to neurological or psychiatric disease even in the absence of any family history of such disease.

Gene mutations have long been known to cause brain cancers, but the effects of other genetic modifications such as those caused by mobile genetic elements are still emerging. There are a few examples of diseases caused by changes in the regulation of mobile genetic element number or activity. For example, Rett syndrome is an X-linked pervasive developmental disorder characterized by a spectrum of disabilities, including abnormal behavior, speech and motor function. More recently, the mutations that cause some cases of ALS (Lou Gehrig's disease) and frontotemporal dementia have been linked to the regulation of mobile genetic elements. These genetic alterations in the brain have such great potential as a source for insight into mental and neurological diseases that the National Institute of Mental Health established a research initiative, the Brain Somatic Mosaicism Network to investigate them.

The genome is the molecular signature of identity.

Linking early experience to the genomic variability of nerves suggests that early experience leaves an irreversible genomic imprint in the brain. This is an intriguing new twist on a debate that has been raging for centuries concerning the importance of nature versus nurture in behavior. This study implies that nature and nurture are not as independent as may have been been imagined, and that nature is not as immutable as once thought. As with all iconoclastic studies, there are caveats to this research, most importantly the fact that the number of mobile genetic elements is much higher in the neurons of the rodents studied here than it is in humans. Furthermore, we don't yet understand how these genetic changes alter the brain activities that give rise to behavior. Nevertheless, this is a provocative study that links early experience with the genetic structure of neurons, and that highlights the remarkable plasticity and adaptability of the brain.

—ROBERT MARTONE

THE ART OF LYING

Lying has gotten a bad rap. In fact, it is among the most sophisticated accomplishments of the human mind. But how can one tell if a person is fibbing?

By Theodor Schaarschmidt

GETTY IMAGES

A 51-year-old man I will call "Mr. Pinocchio" had a strange problem. When he tried to tell a lie, he often passed out and had convulsions. In essence, he became a kind of Pinocchio, the fictional puppet whose nose grew with every fib. For the patient, the consequences were all too real: he was a high-ranking official in the European Economic Community (since replaced by the European Union), and his negotiating partners could tell immediately when he was bending the truth. His condition, a symptom of a rare form of epilepsy, was not only dangerous, it was bad for his career.

Doctors at the University Hospitals of Strasbourg in France discovered that the root of the problem was a tumor about the size of a walnut. The tumor was probably increasing the excitability of a brain region involved in emotions; when Mr. Pinocchio lied, this excitability caused a structure called the amygdala to trigger seizures. Once the tumor was removed, the fits stopped, and he was able to resume his duties. The doctors, who described the case in 1993, dubbed the condition the "Pinocchio syndrome."

Mr. Pinocchio's plight demonstrates the far-reaching consequences of even minor changes in the structure of the brain. But perhaps just as important, it shows that lying is a major component of the human behavioral repertoire; without it, we would have a hard time coping. When people speak unvarnished truth all the time—as can happen when Parkinson's disease or certain injuries to the brain's frontal lobe disrupt people's ability to lie—they tend to be judged tactless and hurtful. In everyday life, we tell little white lies all the time, if only out of politeness: Your homemade pie is awesome (it's awful). No, Grandma, you're not interrupting anything (she is). A little bit of pretense seems to smooth out human relationships without doing lasting harm.

Yet how much do researchers know about lying in our daily existence? How ubiquitous is it? When do children usually start engaging in it? Does it take more brainpower to lie or to tell the truth? Are most people good at detecting untruths? And are we better at it than tools designed for the purpose? Scientists exploring such questions have made good progress—including discovering that lying in young children is a sign that they have mastered some important cognitive skills.

To Lie or Not to Lie

Of course, not everyone agrees that some lying is necessary. Generations of thinkers have lined up against this perspective. The Ten Commandments admonish us to tell the truth. The Pentateuch is explicit: "Thou shalt not bear false witness against thy neighbor." Islam and Buddhism also condemn lying. For 18th-century philosopher Immanuel Kant, the lie was the "radical innate evil in human nature" and was to be shunned even when it was a matter of life and death.

Today many philosophers take a more nuanced view. German philosopher Bettina Stangneth argues that lying should be an exception to the rule because, in the final analysis, people rely on being told the truth in most aspects of life. Among the reasons they lie, she notes in her 2017 book *Deciphering Lies*, is that it can enable them to conceal themselves, hiding and withdrawing from people who intrude on their comfort zone. It is also unwise, Stangneth says, to release children into the world unaware that others might lie to them.

It is not only humans who practice deception. Trickery and deceit of various kinds have also been observed in higher mammals, especially primates. The neocortex—the part of the brain that evolved most recently—is critical to this ability. Its volume predicts the extent to which various primates are able to trick and manipulate, as primatologist Richard Byrne of the University of St. Andrews in Scotland showed in 2004.

Children Have to Learn How to Lie

In our own kind, small children love to make up stories, but they generally tell their first purposeful lies at about age four or five. Before starting their careers as con artists, children must first acquire two important cognitive skills. One is deontic reasoning: the ability to recognize and understand social rules and what happens when the rules are transgressed. For instance, if you confess, you may be punished; if you lie, you might get away with it. The other is theory of mind: the ability to imagine what another person is thinking. I need to realize that my mother will not believe that the dog snagged the last burger if she saw me scarf down the food. As a step to developing a theory of mind, children also need to perceive that they know some things their parents do not, and vice versa—an awareness usually acquired by age three or four.

Theodor Schaarschmidt is a psychologist who earns his living honestly—as a science journalist.

> **Trickery and deceit of various kinds have also been observed in higher mammals, especially primates.**

People cook up about two stories a day on average, according to social psychologist Bella M. DePaulo of the University of California, Santa Barbara, who conducted a 2003 study in which participants filled out "lie diaries." It takes time, however, to become skilled. A 2015 study with more than 1,000 participants looked at lying in volunteers in the Netherlands aged six to 77. Children, the analysis found, initially have difficulty formulating believable lies, but proficiency improves with age. Young adults between 18 and 29 do it best. After about the age of 45, we begin to lose this ability.

A similar inverted U-shaped curve over the life span is also seen with a phenomenon known as response inhibition—the ability to suppress one's initial response to something. It is what keeps us from blurting out our anger at our boss when we are better off keeping silent. The pattern suggests that this regulatory process, which, like deception, is managed by the neocortex, may be a prerequisite for successful lying.

Current thinking about the psychological processes involved in deception holds that people typically tell the truth more easily than they tell a lie and that lying requires far more cognitive resources. First, we must become aware of the truth; then we have to invent a plausible scenario that is consistent and does not contradict the observable facts. At the same time, we must suppress the truth so that we do not spill the beans—that is, we must engage in response inhibition. What is more, we must be able to assess accurately the reactions of the listener so that, if necessary, we can deftly produce adaptations to our original story line. And there is the ethical dimension, whereby we have to make a conscious decision to transgress a social norm. All this deciding and self-control implies that lying is managed by the prefrontal cortex—the region at the front of the brain responsible for executive control, which includes such processes as planning and regulating emotions and behavior.

Under the Hood

Brain-imaging studies have contributed to the view that lying generally requires more effort than telling the truth and involves the prefrontal cortex. In a pioneering 2001 study, the late neuroscientist Sean Spence, then at the University of Sheffield in England, tested this idea using a rather rudimentary experimental setup. While Spence's participants lay in a functional magnetic resonance imaging (fMRI) brain scanner, they answered questions about their daily routine by pressing a yes or no button on a screen. Depending on the color of the writing, they were to answer either truthfully or with a lie. (The researchers knew the correct answers from earlier interviews.) The results showed that the participants needed appreciably more time to formulate a dishonest answer than an honest one. In addition, certain parts of the prefrontal cortex were more active during lying (that is, they had more blood flowing in them). Together the findings indicated that the executive part of the brain was doing more processing during lying.

Several follow-up studies have confirmed the role of the prefrontal cortex in lying. Merely pointing to a particular region of the brain that is active when we tell an untruth does not, however, reveal what is going on up there. Moreover, the situations in these early experiments were so artificial that they had hardly anything in common with people's everyday lives: the subjects probably could not have cared less whether they were dishonest about what they ate for breakfast.

To counter this last problem, in 2009 psychologist Joshua Greene of Harvard University conducted an ingenious experiment in which the participants had a monetary incentive to behave dishonestly. As subjects lay in an fMRI scanner, they were asked to predict the results of a computer-generated coin toss. (The cover story was that this study was testing their paranormal abilities. Even neuroscientists sometimes have to employ misdirection in the name of a higher scientific goal!)

If the volunteers typed the correct response, they were given up to $7. They lost money for wrong answers. They had to reveal their prediction beforehand for half of the test runs. In all the other runs, they merely disclosed after the coin toss whether they had predicted correctly. Subjects were paid even if they lied about their advance conclusions, but not everyone exploited the situation. Greene was able to read the honesty of the participants simply by looking at the hit rates: the honest subjects predicted correctly half the time, whereas the cheaters claimed to have come up with the correct answers in more than three quarters of the runs—a rate too high to be believed. After the study was over, a few liars were bothered by a bad conscience and admitted that they had cheated.

Greene asked himself what distinguished the honest from the dishonest participants. Analysis of the fMRI data showed that when honest subjects gave their answers, they had no increased activity in certain areas of the prefrontal cortex known to be involved in self-control. In contrast, those control regions did become perfused with blood when the cheaters responded. The analysis of reaction times told much the same story. The honest participants did not hesitate even when they were given the opportunity to cheat. Apparently they never even considered lying. Conversely, response time became more prolonged in the dishonest subjects.

Particularly interesting was that the cheaters showed increased activity in the control regions of the prefrontal cortex not only when they chose to behave dishonestly but also when they threw in occasional truths to distract from the lies. Greene suggests that activity in the control regions of the prefrontal cortex in the cheaters may reflect the process of deciding whether to lie, regardless of the decisions those cheaters finally made.

Instead of assessing individual brain regions at the same time as someone told the truth or a lie, psychologist Ahmed Karim of the University of Tübingen in Germany and his colleagues influenced brain activity from the outside, using a method known as transcranial direct-current stimulation—which is safe and painless. In this method, two electrodes are attached to the scalp and positioned so that a weak current hits a selected brain area.

To make the experimental situation as lifelike as possible, the team invented a role-playing game. The test subjects were to pretend they were robbers, sneak into an unobserved room and steal a €20 note from

Liars tend to appear more tense, and their lackluster stories are often thin on detail.

JOSE LUIS PELAEZ INC *GETTY IMAGES*

a wallet in a jacket pocket. They were told that some participants in the study would be innocent. After the theft, they were subjected to an interrogation. If they got through the interrogation without getting tangled up in contradictions, they could keep the money. They were advised to answer as many trivial questions as possible truthfully (for example, giving the correct color of the jacket) because nonguilty people might remember such details just as easily as thieves did but lie at decisive moments (for example, when questioned about the color of the wallet). The electrodes were applied to everyone before questioning, but electrical impulses were administered to only half of the participants (the "test" subjects); the other half served as the control group.

More Effective Deception, Thanks to Brain Stimulation

In Karim's study, the electrodes were arranged to minimize the excitability of the anterior prefrontal cortex, a brain area that earlier studies had associated with moral and ethical decision making. With this region inhibited, the ability to deceive improved markedly. Subjects in the test and control groups lied about as frequently, but those who received the stimulation were simply better at it; their mix of truthful answers and lies made them less likely to get found out. Their response times were also considerably faster.

The researchers ruled out the possibility that brain stimulation had elevated the cognitive efficiency of the participants more generally. In a complicated test of attention, the test subjects did no better than the control group. Apparently Karim's team had specifically improved its test subjects' ability to lie.

One possible interpretation of the findings is that the electric current temporarily interrupted the functioning of the anterior prefrontal cortex, leaving participants with fewer cognitive resources for evaluating the ethical implications of their actions; the interruption allowed them to concentrate on their deceptions. Two follow-up studies conducted by other teams were also able to influence lying using direct current, although they used different experimental setups and target brain regions. But all the test subjects in these studies lied at essentially the press of a button. Whether electrically stimulating selected brain areas would work outside the laboratory is unknown. In any case, no instrument has yet been developed that can test such a hypothesis.

Challenges of Lie Detection

On the other hand, devices that supposedly measure whether a person is telling the truth—polygraphs—have been in use for decades. Such tools are desirable in part because humans turn out to be terrible lie detectors.

In 2003 DePaulo and her colleagues summarized 120 behavior studies, concluding that liars tend to seem more tense and that their stories lack vividness, leaving out the unusual details that would generally be included in honest descriptions. Liars also correct themselves less; in other words, their stories are often too smooth. Yet such characteristics do not suffice to identify a liar conclusively; at most, they serve as clues. In another analysis of multiple studies, DePaulo and a co-author found that people can distinguish a lie from the truth about 54 percent of the time, just slightly better than if they had guessed. But even those who encounter liars frequently—such as the police, judges and psychologists—can have trouble recognizing a con artist.

Polygraphs are meant to do better by

measuring a variety of biological signs (such as skin conductance and pulse) that supposedly track with lying. Gestalt psychologist Vittorio Benussi of the University of Graz in Austria presented a prototype based on respiration in the early 1910s, and detectors have been refined and improved ever since. Even so, the value continues to be a matter of contention. In 1954 the West German Federal Court of Justice banned polygraph use in criminal trials on the grounds that such "insight into the soul of the accused" (as a 1957 paper on the ruling put it) would undermine defendants' freedom to make decisions and act. From today's perspective, this reasoning seems a bit overdramatic; even the latest lie detectors do not have that ability. More recent criticisms have been leveled at their unreliability.

So far courts have rejected fMRI lie detectors as evidence. The efficacy of the method has simply not been adequately documented.

Courts in other countries do accept results from lie-detector tests as evidence. The case of George Zimmerman, a neighborhood-watch volunteer who, in 2012, shot a black teenager—Trayvon Martin—supposedly in self-defense, is well known. Zimmerman's acquittal triggered a debate about racism across the U.S. The police interrogation involved a particular variant of a lie-detector test that includes what is called computer voice-stress analysis. This analysis was later placed in evidence to prove the innocence of the accused, despite vehement scientific criticism of the method.

Polygraphs do detect lying at a rate better than chance, although they are also frequently wrong. A questioning technique known as the guilty knowledge test has been found to work well in conjunction with a polygraph. The suspect is asked multiple-choice questions, the answers to which only a guilty party would know (a technique very similar to the study involving the pickpocket role-playing described earlier). The theory behind it holds that when asked questions that could reveal guilt ("Was the wallet red?"), a guilty person exhibits more pronounced physiological excitation, as indicated by elevated skin conductance and delayed response time. This method has an accuracy of up to 95 percent, with the innocent almost always identified as such. Although this test is by far the most precise technique available, even it is not perfect.

Recently experiments have been conducted to evaluate whether imaging techniques such as fMRI might be useful for detecting lies. The proposed tests mostly look at different activation patterns of the prefrontal cortex in response to true and false statements. In the U.S., a number of companies are marketing fMRI lie detection. One advertises itself as useful to insurance companies, government agencies and others. It even claims to provide information relating to "risk reduction in dating," "trust issues in interpersonal relationships," and "issues concerning the underlying topics of sex, power, and money."

But fMRI approaches still have shortcomings. For one thing, differences in responses to lies and truths that become evident when calculating the average results of a group do not necessarily show up in each individual. Moreover, researchers have not yet been able to identify a brain region that is activated more intensely when we tell the truth than when we lie. As a result, a person's honesty can be revealed only indirectly, by the absence of indications of lying. Another problem is Greene's finding that elevated blood perfusion in parts of the prefrontal cortex might indicate that a person is *deciding* whether to lie and not necessarily that the person is lying. That ambiguity can make it difficult to interpret fMRI readings.

So far courts have rejected fMRI lie detectors as evidence. The efficacy of the method has simply not been adequately documented. A machine that reads thoughts and catches the brain in the act of lying is not yet on the near horizon.

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MORE TO EXPLORE

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Sex, Drugs and Self-Control

It's not just about rebellion. Neuroscience is revealing adolescents' rich and nuanced relationship with risky behavior

By Kerri Smith

CAVAN IMAGES *GETTY IMAGES*

Cole Skinner was hanging from a wall above an abandoned quarry when he heard a car pull up. He and his friends bolted, racing along a narrow path on the quarry's edge and hopping over a barbed-wire fence to exit the grounds.

The chase is part of the fun for Skinner and his friend Alex McCallum-Toppin, both 15 and pupils at a school in Faringdon, U.K.. The two say that they seek out places such as construction sites and disused buildings—not to get into trouble, but to explore. There are also bragging rights to be earned. "It's just something you can say: 'Yeah, I've been in an abandoned quarry'," says McCallum-Toppin. "You can talk about it with your friends."

Science has often looked at risk-taking among adolescents as a monolithic problem for parents and the public to manage or endure. When Eva Telzer, a neuroscientist at the University of North Carolina at Chapel Hill, asks family, friends, undergraduates or researchers in related fields about their perception of teenagers, "there's almost never anything positive," she says. "It's a pervasive stereotype." But how Alex and Cole dabble with risk—considering its social value alongside other pros and cons—is in keeping with a more complex picture emerging from neuroscience. Adolescent behavior goes beyond impetuous rebellion or uncontrollable hormones, says Adriana Galván, a neuroscientist at the University of California, Los Angeles. "How we define risk-taking is going through a shift."

Adolescents do take more risks than adults, and the consequences can include injury, death, run-ins with the law and even long-term health problems. But lab studies in the past decade have revealed layers of nuance in how young people assess risks. In some situations, teenagers can be more risk-averse than their older peers. And they navigate a broader range of risks than has typically been considered in the lab, including social risks and positive risks—such as trying out for a sports team. These types of behavior seem to have different effects on the brain.

How adolescents interact with risk is important. Work on the neural underpinnings of risky behavior can inform guidelines and laws for teens who drive, for example, or the punishments they receive for violent crimes. Understanding how the teenage brain evaluates risk could even reveal predictors of mental-health conditions such as schizophrenia and depression, which often emerge in adolescence.

In more ways than one, there is a lot going on in a teenager's head. "In fact, it's just beautiful," says B. J. Casey, a neuroscientist at Yale University. "It's amazing that it unfolds correctly most of the time."

Rebel with a Cause

Adolescence is a perilous period. The death rate among 15- to 19-year-olds worldwide is about 35 percent higher than that among 10- to 14-year-olds. And risky behaviors are linked to many of the major threats to life during this time (*see graphic on next page*). Road injuries are the biggest cause of death for adolescents globally. Self-harm and other forms of violence also rank highly. Plus, some practices that can lead to poor health in adulthood—such as use of tobacco or alcohol, or sedentary lifestyles—often stem from poor choices made in the teenage years. So, risky behavior has been a preoccupation for scientists.

"Risk-taking has driven a lot of the early

Kerri Smith works for *Nature* magazine.

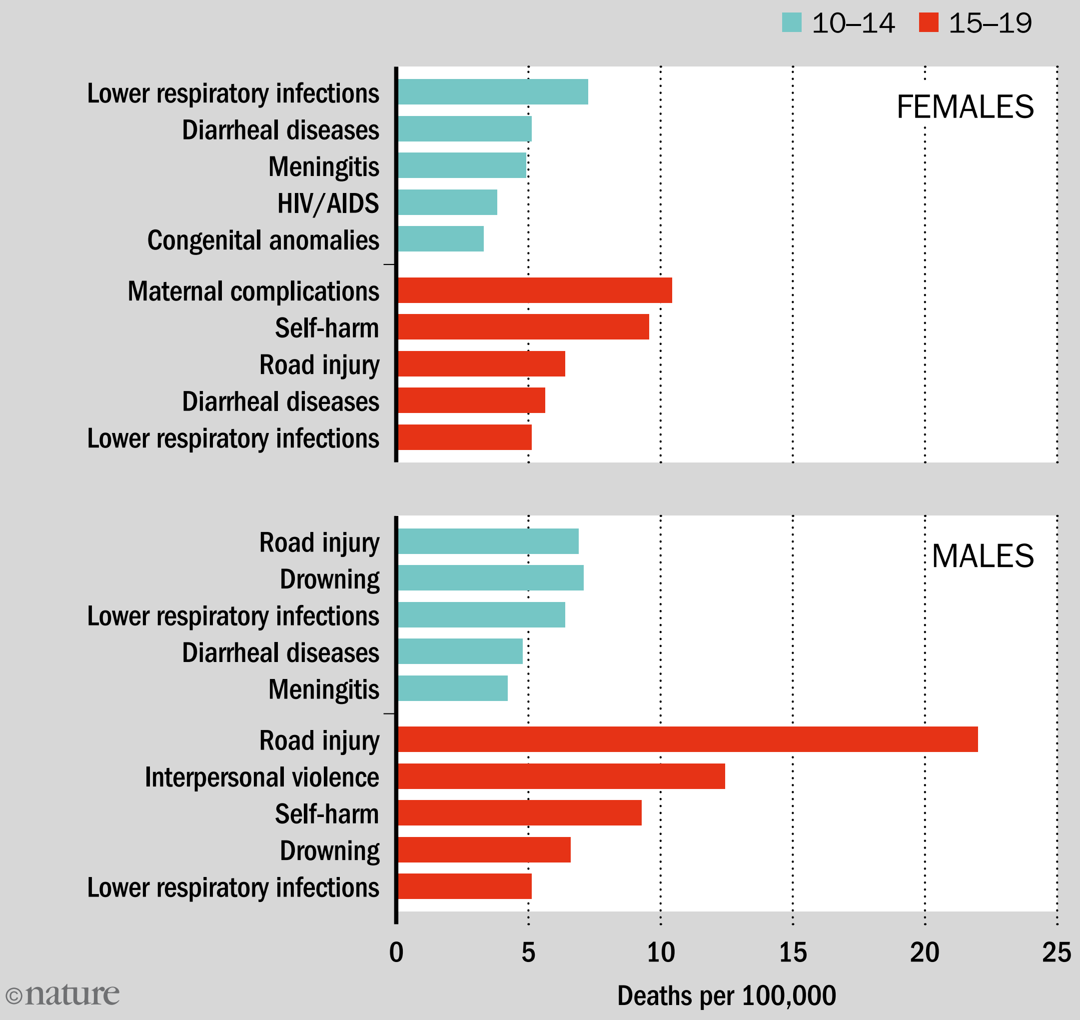
work" on the teenage brain, says Ronald Dahl, who studies adolescent brain development at the University of California, Berkeley. "It was a route to successful funding, so it was emphasized."

Early theories focused on a perceived imbalance in the developing brain. Areas linked with impulsivity and heightened sensitivity to reward, especially in the social realm, get an early boost in activity, whereas those governing cognitive processes such as working memory develop smoothly throughout adolescence.

Neuroscientists likened the emerging picture of the teenage brain to that of a car with a revving accelerator and faulty brakes. This fit the developmental data, but not the fact that many teenagers show no proclivity for risk-taking, says Ted Satterthwaite, a psychiatrist and neuroimaging researcher at the University of Pennsylvania. A 2016 survey of more than 45,000 U.S. teenagers found that 61 percent had not tried cigarettes by age 17–18, for example; some 29 percent had never drunk alcohol.

RISKING LIFE AND LIMB

In 2015, an estimated 1.2 million people aged 10-19 died. Many of the leading causes of death, particularly for older adolescents and males, are related to risky behaviors.



Most neuroscientists now acknowledge that neural systems developing at different rates do not mean that the brain is unbalanced. "It's a vulnerable period, but it's not vulnerable just because there's something going wrong with their brains," says Satterthwaite.

And so work has shifted to looking at a broader range of risks and environmental influences. For many teenagers, says Dahl, there is risk in relatively benign experiences, such as standing up for a friend or asking someone on a date. "Taking a social risk—those feel more salient."

The Social Whirl

In recent years, studies have begun to characterize how social elements influence risk. In 2009, Laurence Steinberg, a psychologist at Temple University, got teenagers to lie in a functional magnetic resonance imaging (fMRI) scanner and play "the chicken game"—a video game in which they drive a car, passing through an implausible 20 traffic lights in 6 minutes. As the first lights change to amber, some teenagers choose to carry on; others wait for green. Sometimes speeding ahead pays off, but sometimes the car gets hit.

When teenagers played this game alone, they took risks at about the same frequen-

FROM: "SEX AND DRUGS AND SELF-CONTROL: HOW THE TEEN BRAIN NAVIGATES RISK," KERRI SMITH IN *NATURE*, VOL. 554, PAGES 426–428; FEBRUARY 21, 2018; SOURCE: WHO

cy as adult players. But when Steinberg told the adolescents that their friends were watching from an adjacent room, they took significantly more risks. In a similar study by Telzer and her colleagues, teenagers took fewer risks when they were told that their mothers were watching. The scanner revealed greater activation in reward-sensitive brain regions, such as the ventral striatum, with the friend-influenced risky behaviors. Meanwhile, the mothers' presence correlated with activation in the prefrontal cortex, an area known to be involved in cognitive control.

Neuroscientists have used this game to test how a teenager's propensity to take risks can depend on their social stature. In one study, a team at the University of Oregon got adolescents to play it in a scanner after hearing that two other teenagers were watching. Then the researchers got the participants to play another video game, in which they were excluded from throwing and catching a ball with the same peers.

When they returned to the driving game after experiencing social exclusion, adolescents who said they were sensitive to peer influence took significantly more risks. Those who demonstrated this pattern also showed greater activation in a brain area involved in modelling the thoughts of others, the temporoparietal junction. In another study, Telzer and her colleagues found that teenagers who were more socially excluded or victimized took more risks. The work is part of a drive to understand who is most vulnerable. "If we know the context under which teens smoke or make good or bad decisions, we can push them into the contexts that are more positive," says Telzer.

"It's a vulnerable period, but it's not vulnerable just because there's something going wrong with their brains." –Ted Satterthwaite

Peers can have positive effects, too. In a 2014 study, teenagers were asked to donate or keep money in an online game, supposedly watched by ten peers. If a participant made a donation and their peers approved—denoted by a "thumbs up" icon—the participant made more donations during the game. (Although the opposite is also true.) "There's an assumption that teenagers' friends are a monolithic negative influence," says Telzer. The real picture is more complex.

Interestingly, the same brain systems that mediate unhealthy risk-taking also seem to help teenagers to take positive risks. Activity in the ventral striatum, particularly rising numbers of dopamine receptors, has been linked to the greater sensitivity that teenagers feel to rewards for positive as well as perilous behaviors.

Telzer's studies suggest that teenagers who show heightened ventral striatum activity when making decisions that help others, such as donating money, take fewer risks in the long term and have a lower risk of depression as adults. "There's very much a yin and yang to this," says Dahl.

There are limitations to these lab-based studies; it's hard to reproduce the social whirl of teenage life in a scanner, says Galván. "How do we emulate what's going on on Saturday night in a cold lab on a Tuesday afternoon?" she asks. The studies are more likely to capture a teenager's inclination for risk than the likelihood of real-world risk-taking, Galván says.

The other problem is that the average teenager in a study is only moderately likely to take risks. "Most of what we know about adolescent risk-taking is actually derived from relatively normative samples," says Telzer, "not adolescents engaging in high levels of risk-taking behavior." Dangerous risk-taking could be confined to a small proportion of teenagers, and there is evidence that they process risk very differently from their peers.

Interestingly, the same brain systems that mediate unhealthy risk-taking also seem to help teenagers to take positive risks.

High-Risk Research

Telzer ran an as-yet-unpublished study in 2015 with adolescents who had been expelled from a school for serious offences. Her team asked them to lie in a scanner and push a button when they saw letters on a screen, but not if the screen displayed an X. Images with social significance—positive pictures such as teenagers laughing or playing games on a beach, and negative ones, including a group ganging up on someone—also appeared on screen. Most teenagers were worse at the button-pressing task when the images were positive; their cognitive control was overridden by the rewarding picture. Activity in the ventral striatum went up in tandem. But among the expelled or suspended students, it was the aversive pictures that impaired performance. The teenagers' lack of control, Telzer says, seems to come from a different type of reaction to social stimuli.

Scientists have assumed that the young people who take the most risks show an extreme version of the standard teenager brain profile, says Telzer. But perhaps, she says, they are "a very different type of adolescent."

Research on risk-taking has begun to inform the U.S. justice system. Authorities are taking into account, for example, the factors that might impair a teenager's self-control. Studies show that in emotionally neutral situations, young adults perform cognitive tasks just as well as older adults. But when the situation is emotionally charged, their performance drops off. This and other work could suggest that crimes in emotionally "cold" situations should be considered differently from those in which "hot," or emotionally led, decision-making takes over. Similar work could provide ways of pinpointing teenagers at high risk of doing something dangerous.

Steinberg testified in five court cases last year concerning criminal sentences for adolescents. After hearing his evidence on how decision-making in teens is influenced by emotion, a Kentucky court last year decided to raise to 21 the age at which individuals could be given the death penalty. And the evidence has also been enlisted in arguments against mandatory life sentences without parole for offenders under 21.

> “Every time I give a talk, I ask people to raise their hand if they want to go through adolescence again. And no one does.”

Scientists are excited about the possibility that this body of developmental research can inform policy. But some, such as Satterthwaite and Galván, point out some challenges in using fMRI data in court for individual cases. The data from neuroimaging studies are usually averaged out across participants, so drawing conclusions about any one brain is itself risky. “Honestly, I don’t think neuroimaging should be used,” Satterthwaite says. “It’s too noisy.”

The data are also too noisy for diagnosis, but Satterthwaite is tantalized by evidence that the young brain’s response to risk might reveal early symptoms of depression or anxiety. He would like to see research get to the point at which it could guide clinical treatment. “The idea that you can come see me with a life-threatening condition, and leave with no diagnostic test, no imaging, no lab test—that’s medieval,” he says.

The broader research on adolescent risk is already helping to minimize dangerous behavior in daily life. For instance, adolescents who don’t get enough sleep are more prone to a host of risk-taking behaviors, such as smoking and sexual activity. Dozens of studies on the effects of increasing sleep by delaying school start times—a move endorsed by bodies such as the U.S. Centers for Disease Control and Prevention and the American Academy of Pediatrics—suggest that many of these problems, including risky behaviors, improve when schools start later. The academy recommends a start time of 8:30 or later; hundreds of schools in the United States have delayed their first bell, but in 2014 the median start time for middle school was still 8:00.

Steinberg has advocated limiting exposure to risk in the first place, for example by raising the minimum age for buying tobacco to 21 or prohibiting alcohol sales within 300 meters of schools. This is likely to work better than approaches based on informing students about risks, he says. Other policies aim to take away the opportunity for dangerous behavior. Graduated-licensing schemes in Australia, New Zealand, Northern Ireland and the United States compel young drivers to build up experience before they are allowed to drive with only teenage passengers. Such programs have been shown to reduce casualties among young drivers.

But a little bit of risk is a good thing, says Casey. “I wouldn’t say that we want people to stop taking risks,” she says. “A lot of it is allowing them to be adults in safe situations.”

Adolescents have a lot to learn in their transition to relative independence—and nobody said it was easy. “I can’t think of a more challenging period of development,” says Casey. “Every time I give a talk, I ask people to raise their hand if they want to go through adolescence again. And no one does.”

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Egyptian fruit bat

Bat Man

How does the brain know where it is? Nachum Ulanovsky hopes his flying friends can help him find the answer

By Alison Abbott

GETTY IMAGES

On a sun-parched patch of land in Rehovot, Israel, two neuroscientists peer into the darkness of a 200-meter-long tunnel of their own design. The fabric panels of the snaking structure shimmer in the heat, while, inside, a study subject is navigating its dim length. Finally, out of the blackness bursts a bat, which executes a mid-air backflip to land upside down, hanging at the tunnel's entrance.

Nachum Ulanovsky, the study leader, looks affectionately at the creature as his graduate student offers it a piece of banana—a reward for the valuable data it has just added to their latest study of how brains navigate.

The vast majority of experiments probing navigation in the brain have been done in the confines of labs, using earthbound rats and mice. Ulanovsky broke with the convention. He constructed the flight tunnel on a disused plot on the grounds of the Weizmann Institute of Science—the first of several planned arenas—because he wanted to find out how a mammalian brain navigates a more natural environment. In particular, he wanted to know how brains deal with a third dimension.

The tunnel, which Ulanovsky built in 2016, has already proved its scientific value. So have the bats. They have helped Ulanovsky to discover new aspects of the complex encoding of navigation—a fundamental brain function essential for survival. He has found a new cell type responsible for the bats' 3D compass, and other cells that keep track of where other bats are in the environment. It is a hot area of study—navigation researchers won the 2014 Nobel Prize in Physiology or Medicine and the field is an increasingly prominent fixture at every big neuroscience conference.

"Nachum's boldness is impressive," says Edvard Moser of the Kavli Institute for Systems Neuroscience in Trondheim, Norway, one of the 2014 Nobel laureates. "And it's paid off—his approach is allowing important new questions to be addressed."

And for brain scientists hitting the limits of what they can learn from highly simplified behavior in the lab, Ulanovsky is a pioneer of "natural neuroscience." Over the years, his arenas and tunnels have been getting larger, more sophisticated and less like an artificial lab environment. Up next is a giant maze that will allow his team to ask even more advanced questions about how the brain copes with making decisions—such as which way to turn—on the wing. "If we want to really understand how the brain works, we need to study animals doing more natural tasks," says Dora Angelaki, a neuroscientist at Baylor College of Medicine. "More of us are finally starting to realize this."

Armed for Science

When Ulanovsky opened his lab at the Weizmann Institute in 2007, he was completing a circular flight path of his own. His family emigrated from Moscow to Israel in 1973, when he was just four months old, and settled in Rehovot. As a child, Ulanovsky played in the Weizmann's subtropical gardens and attended science events for local children and young people.

Once they turn 18, most physically fit Israelis enter compulsory military service. But Ulanovsky didn't want to lose academic momentum when he graduated from high school at 16, so he enrolled in a three-year physics course at Tel Aviv University—even though that meant starting his military ser-

Alison Abbott works for *Nature* magazine.

vice late and, as a result, serving for a longer period.

His service proved productive. In addition to getting general military training, he was put in a research and development division because of his physics background. Over five years, he learned technical skills such as designing high-tech instruments and programming that would later prove invaluable in designing arenas and sensors for his bats. The army allowed him time off to take courses that supported his growing interest in biology. He left the army intent on becoming a neuroscientist, and launched into a PhD at the Hebrew University in Jerusalem, studying how the cat brain processes auditory signals.

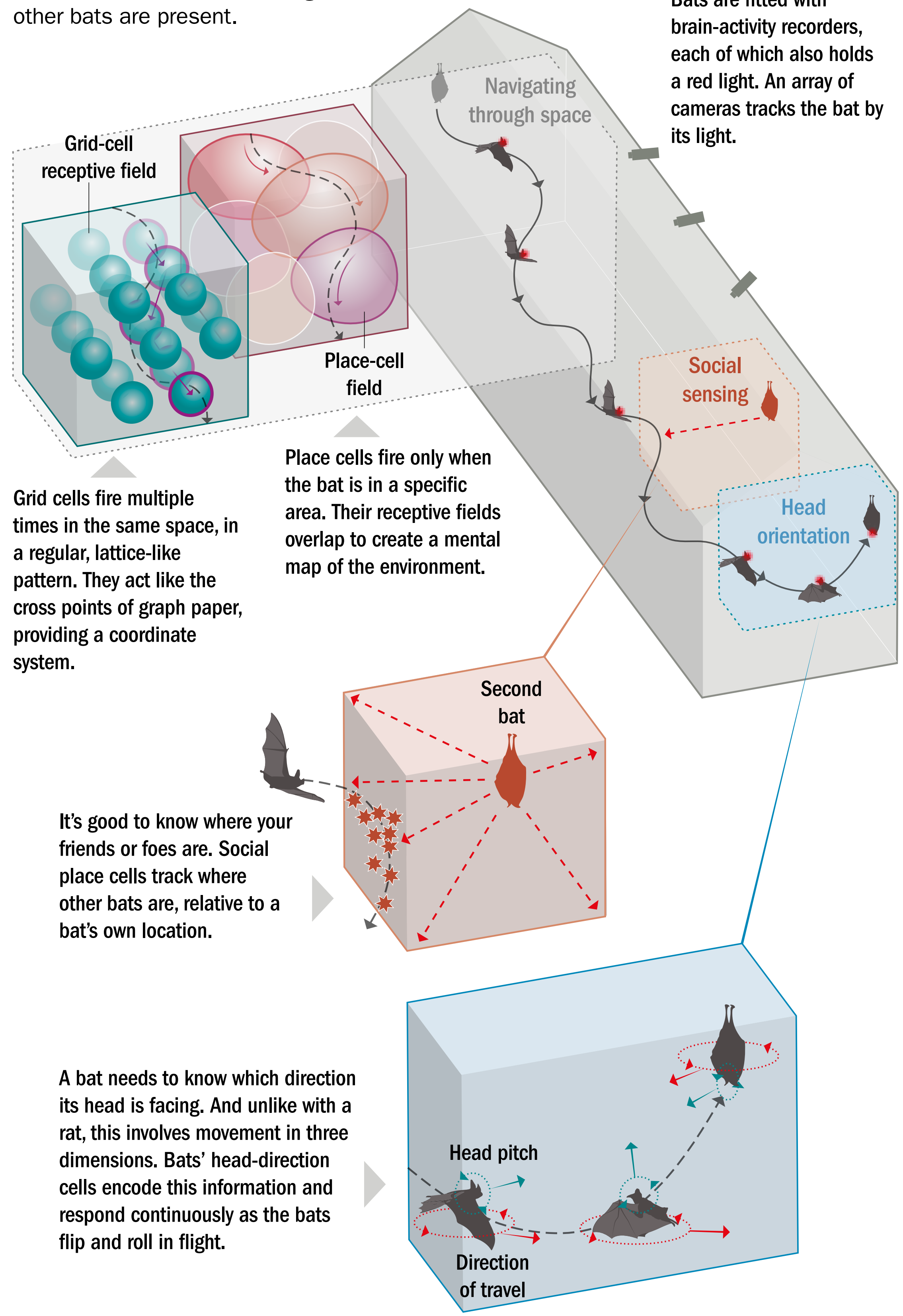
He discovered that auditory neurons have their own type of memory, and promptly immersed himself in the voluminous memory literature, where he discovered the overlapping field of navigation (animals have to remember where they have been to navigate, and it is not by chance that memory and navigation are processed in the same brain area). The field was dominated by studies in ground-based rats and mice, whose navigational experience is relatively easy to measure as they scuttle around small boxes in labs. But the question of how different animals perceive the world as they move vertically—swimming, climbing trees or flying—had not been seriously addressed. Ulanovsky decided that to study the brain's complex navigational code more holistically, he needed a mammal whose route-finding experience is mostly 3D, which led him to the only flying mammal: the bat.

He joined a bat lab at the University of Maryland in College Park to learn more about the creatures. He found several similarities to rodent models of navigation, discovering that bats, too, use special cells to get around. By 2007, Ulanovsky had his own bat lab and a tenure-track position at the Weizmann.

Ulanovsky is a composed per-

Flight Trackers

Several groups of cells in the hippocampal brain region help bats to navigate. They provide information on where the bats are, the direction their heads are facing and whether other bats are present.



NIK SPENCER *NATURE*

son, but his equanimity can wobble when he talks about bats. His voice gets louder by a few decibels, and his face lights up. “In the West, people are frightened by creatures of the night—in Hollywood movies, when the heroine goes into a dark building and bats come rushing out, you know something bad is going to happen.” The fear is misplaced, he says. “In China, bats are considered a good omen.”

Space Odyssey

Neuroscientists have been mesmerized by how the brain encodes its spatial environment ever since the 1970s, when John O’Keefe at University College London found that the rat brain had a neat way to know where the animal is. When he placed electrodes in a region of the brain called the hippocampus, O’Keefe found neurons that fired only when a rat was in a particular location in its enclosure, creating a sort of cognitive map. He called them “place cells.” Nearly three decades later, Edvard Moser and May-Britt Moser, also at the Kavli Institute, discovered another type of way-finding cell in the nearby entorhinal cortex: grid cells, which fire not just at a single place in the enclosure, but at multiple points arranged in a hexagon. These cells make up a brain code that allows the animal to keep track of its relative position in space, much like a tiny Global Positioning System (GPS). The Mosers shared the 2014 Nobel Prize with O’Keefe; they and other scientists have also discovered other types of navigation cell in the hippocampal area, including those that fire in response to head direction, or to a border such as a cage wall.

Nachum Ulanovsky with one of his research bats.

DAVID VAAKNIN *FOR NATURE*

Almost all of these discoveries came from rats: animals that—aside from, say, raising themselves on their hind legs to sniff, or accidentally falling from shelves—live their lives on the horizontal. One imaginative attempt to get around this monitored rats with implanted electrodes in weightless conditions during a 1998 flight on a NASA space-shuttle, but the result was inconclusive.

For Ulanovsky, the virtues of bats extended beyond the animals' suitability for understanding 3D mapping: he wanted to work with a wild animal, to build a better picture of natural behavior. He started to think that highly controlled lab experiments, so crucial to understanding some basic properties of neurons, needed a reality check. "We don't know nearly enough about how all these cells work together to map the environment that animals inhabit in the wild," he says. So he reasoned that bats caught from the wild and flown in less constrained environments would be the ideal subjects. Moreover, Ulanovsky was convinced that studying the system in something other than a lab rodent would help to identify which aspects of behavior cut across species.

Edvard Moser agrees that studying the same skill in many species is important. "Knowing the different ways it is possible to solve the same problem will help us learn in general terms how brains, including the human brain, work."

Bat Cave

Before Ulanovsky could put his ideas to the test, he had to find the right sort of bat, check how it explored its natural environment and, most challengingly, design instruments to collect data from the bat and its brain.

Data from the brains of rats running around small enclosures are generally picked up by implanted electrodes and transferred to computers using cables. "Clearly, that won't work in flying bats," says Ulanovsky. He set about designing wireless GPS and electrophysiology devices that are small enough for a bat to carry. It was a technical challenge, and he might not have succeeded without his army training in instrumentation and software, he says.

His GPS logger is a 5-square-centimeter device tipping the scales at 8 grams. His neural logger, with 16 spindly electrodes—each thinner than a human hair—weighs in at just 7 grams. It is sensitive enough to record several individual neurons firing, and it can store many hours' worth of data.

Tiny as they are, these loggers are too heavy for many bats to carry—including the delicate 20-gram bat *Eptesicus fuscus*, commonly known, ironically, as the big brown bat, and the species Ulanovsky studied when he was at Maryland. Instead, he settled on using the Egyptian fruit bat (*Rousettus aegyptiacus*). It's ten times larger, approaching the size of an average laboratory rat, and common in Israel. "That was the low-tech part of my approach to miniaturization—choose a bigger bat," says Ulanovsky.

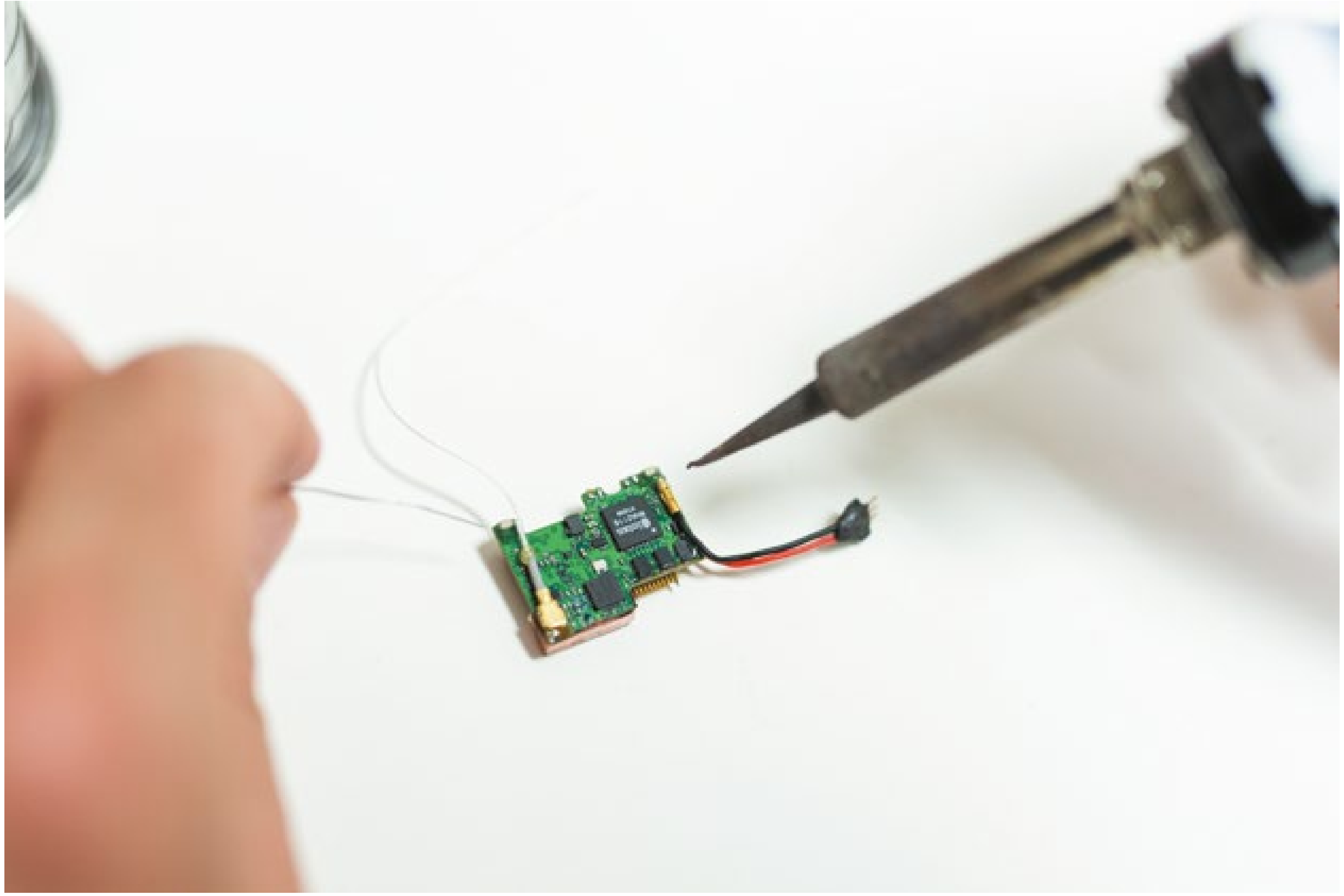
Some bats can be vicious, but Egyptian fruit bats, he says, "are easy to tame and very nice to work with." A couple of times a year, he picks up a giant net and heads out on a bat-catching safari, collecting specimens from colonies that inhabit abandoned buildings, or caves in the Judean hills.

One of his earliest experiments, started in 2008, aimed to find out how far his bats chose to fly when left to their own devices. Very little was known about the natural behavior of bats, he says, so he needed to gather some basic information. He armed 35 bats with GPS loggers and discovered that they flew 15 kilometers or more each night to find dinner—remembering the exact location of a particular heavily fruited tree.

He also built flight rooms in his labs. The largest is about 6 × 5 × 3 meters—close to half the size of a squash court—and is decked out with cameras, landing balls for the bats to hang from and feeding stations where they can be tempted with fruit. Clad in metal and a layer of black acoustic foam to shield it from external noise and electrical signals, the room is silent. The lighting can be adjusted from dim to very dim.

In the control room next door, the bats appear as tiny dots of light moving across a screen. Each bat carries a red light-emitting diode (LED), tracked by the cameras as the animals flit about the room. Their brain activity is monitored with a neural logger whose electrodes are surgically implanted into the hippocampus and whose external hardware is fixed to the skull with tiny screws. The cameras and loggers enable Ulanovsky to correlate the firing of neurons with the bats' exact position in space.

In this setup, he has been able to reveal the 3D territory of a typical bat-nav neuron. For example, place-cell fields—measured in rats as flat circles of a particular size—turned out in flying bats to be almost spherical, showing none of the vertical elongation that some rat experiments had predicted. He worked out how head-direction cells operate as a 3D compass, and discovered another type of navigation cell—the long-sought vector cell—which tracks angle and distance



A neural logger designed for wireless recording of neurons in flying bats.

DAVID VAAKNIN *FOR NATURE*

to a particular goal. One series of experiments helped put to rest a once-popular theory from rat studies that proposed that a certain type of brain oscillation creates grid-like neural maps; the oscillation turned out to be absent in bats, and therefore not necessary for such map-building.

He also explored the influence of a bat's social world. When he put a companion bat into the flight room, he discovered that the monitored bat had "social place cells" that track the companion's position. He'd imagined that such cells must exist somewhere in the brain—bats obviously need to know where their fellow bats are, as well as their predators—but was not expecting they would necessarily show up inside the hippocampus. He is now monitoring how the brains of two or three bats register the social interaction of up to ten companion bats living together in the large flight room for several months.

But Ulanovsky's burning question was how this set of navigation cells would perform outside a flight room, during more natural behavior. It would be impossible to monitor the positions of bats in the wild—cameras would be no use because the bats' ranges are too large, and GPS would not give high enough resolution—so Ulanovsky decided that an artificial tunnel was the best option.

As a bat flies through the 200-metre tunnel, he can monitor its exact position using a tiny signalling device on the bat itself and a suite of 15 antennas placed at intervals outside the structure to pick up its radio transmissions. Each antenna sends its computed distance from the signalling tag by Wi-Fi to a workstation at the tunnel entrance, where the full 3D movement of the bats is recreated. The whole set-up cost around 900,000 Israeli shekels (US$250,000) to construct.

From the bats' point of view, flapping through the tunnel is much easier than a 15-kilometer night-time foray to distant fruit trees.

From the bats' point of view, flapping through the tunnel is much easier than a 15-kilometre night-time foray to distant fruit trees. But Ulanovsky's team has tried to recreate some of the features that the brain uses as navigational aids. Graduate student Tamir Eliav collected a variety of objects and scattered them at intervals along the tunnel for the bats to use as fixed points in their internal map. Walking along the tunnel's length in the low glow of a dim LED strip light, past an old chest of drawers and a rusting bicycle rack, feels like being in an art installation.

Since the inaugural flight in March 2016, Ulanovsky and his students have collected data from more than 200 neurons across different bats. These early data hint at interesting insights. For example, Ulanovsky found that a single cell would fire at one location in a small area but also at a quite different location in a large area, indicating that place cells might represent multiple spatial scales, not just one particular scale. Researchers hadn't been able to spot this pattern in experiments in small enclosures. Ulanovsky needs more data to confirm this, but it would be in line with the predictions of some theoreticians. "If place cells all had small, laboratory-sized place fields, there would not be enough neurons in the hippocampal area to individually cover the great distances that bats travel," says Ulanovsky, "so it makes sense that some place cells respond to multiple scales."

Tunnel Vision

That's motivated him to design a bigger and better tunnel. Earlier this year, a private sponsor provided half of the 9 million shekels needed to build a kilometre-long tunnel with more densely positioned, wired antennas. This will allow measurement of even larger place fields, with more precise 3D localization. This tunnel will have a 15-metre side branch to allow the scientists to study how the same neurons respond to short and long flights, and how the brain stitches together these two scales. Air conditioning will allow experiments to run throughout the blistering summer.

The tunnel and its once-wild bats represent a useful halfway house between the real world and the lab, says Angelaki, who researches spatial navigation and decision-making in the brains of mice and monkeys.

"Behavioral neuroscientists like myself are increasingly realizing how important it is to move away from overtrained lab-animal brains," she says. In typical lab experiments, animals are trained in a very specific, usually unnatural, task. "That may not have anything to do with how that animal has evolved brain connectivity to optimize foraging in the wild," she says.

Like others around the world, Angelaki's lab is starting to use neural loggers to monitor more natural rodent behavior, such as foraging for food scattered in their enclosures. She predicts that more researchers will start setting up their experiments with an eye on the natural world. "Over the next five years or so, results will start to emerge and there will be a big change in neuroscience practice," she says.

However, as Moser notes, Ulanovsky's bats aren't yet doing anything as clever as finding a fruit tree in the wild. "It doesn't take much thought to fly up and down a tunnel," he says. So Ulanovsky is nursing an even bigger mind-reading ambition. He is seeking funding for a maze 40 meters wide and 60 long—a little under half the size of a football pitch—to test how bat brains represent more complex environments, then plan and make decisions about how to navigate them.

The maze will be made up of interconnected tunnels in which the bat won't always be able to see its goal (usually a food treat such as a piece of banana). It will instead have to rely on memory in its cognitive map. Ulanovsky has a series of increasingly complex experiments in mind—setting up multiple goals, for example, or suddenly blocking a path that the bat had memorized. He has questions about how bats choose between several goals, or recompute a path, or how cells respond when a bat loses its way. "Do the vectors in the brain start rotating wildly?" he wonders. "These are all fascinating questions to which we have no answers."

And the bats are obliging subjects. On a good day in the tunnel, a bat can soar and wheel for thousands of meters before taking a break for its banana. "They are misunderstood creatures," says Ulanovsky, standing at the end of the tunnel and gazing at a just-landed bat with obvious tenderness. "And they will help science."

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PERY BURGE *GETTY IMAGES*

OPINION

Yes, Make Psychedelics Legally Available, but Don't Forget the Risks

Psychedelics have psychological and spiritual benefits, as a new best seller claims, but they're far from a panacea

By John Horgan

Last spring, I descended into the basement of a suburban home with two dozen people and swilled fluid from a plastic cup. It was ayahuasca, a tea brewed from two South American plants, which contains the psychedelic compound dimethyltryptamine, DMT.

Ayahuasca has the viscosity of spit, it tastes like beer dregs into which someone has dropped a cigar, and it is nauseating, literally. Our guides gave each of us a plastic pail in case we vomited (which I did). The brew induces visions that can be blissful, excruciating, terrifying, sometimes all at once. As our guides played music and sang, we groaned, retched, cried, laughed, stared open-mouthed into space, retched again. A young man beside me oscillated between giggles and sobs. We each paid $200 for this experience, which lasted about five hours.

Why, you might ask, would anyone in his right mind want to do this? I raised this question 15 years ago in *Rational Mysticism*, my investigation of psychedelics, meditation and other mystical technologies (and I'll tell you my answer below). That same year, 2003, I proposed in *Slate* that psychedelics be dispensed by "licensed therapists, who can screen clients for mental instability and advise them on how to make their experiences as rewarding as possible."

This scenario seemed far-fetched at the time, but it is looking a lot more likely lately. One reason is that researchers have continued producing evidence of psychedelics' psychological and spiritual benefits. Perhaps more important, journalist Michael Pollan—author of the best sellers *The Botany of Desire* and *The Omnivore's Dilemma*—has become an advocate of the drugs.

Pollan wrote a surprisingly enthusiastic article about psychedelics for *The New Yorker* in 2015. That was a preview of his new best seller *How to Change Your Mind: What the New Science of Psychedelics Teaches Us about Consciousness, Dying, Addiction, Depression, and Transcendence*. I'm a fan of psychedelic literature, including the writings of Aldous Huxley, Terence McKenna and Alexander and Ann Shulgin, but I haven't read a more eloquent defense of psychedelics than *How to Change Your Mind*.

Pollan serves as an ideal guide, especially for those who are curious about magic mushrooms and LSD but haven't dared try them. Far from being a thrill-seeker, Pollan is nervous about psychedelics' ill effects—with good reason, because he's had heart trouble. He's an atheist skeptical of all supernatural claims, but he's also curious and open-minded. And he's an exceptionally clear writer, even when describing experiences that defy description. He reminds me of another hyper-rational explorer of spirituality, Robert Wright, author of last year's best seller *Why Buddhism Is True*.

Pollan recounts the discovery of LSD's effects by chemist Albert Hofmann in 1943, the subsequent surge of scientific interest in psychedelics and the backlash against them in the 1960s, often blamed on aggressive proselytizing by psychologist-turned-guru Timothy Leary. This history provides the backdrop for Pollan's investigation of sanctioned studies at universities in the U.S. and Europe and of the underworld of psychedelic psychotherapy.

To supplement this third-person reporting, Pollan ingests psilocybin, LSD and ayahuasca and smokes toad venom (which like ayahuasca contains DMT).

John Horgan directs the Center for Science Writings at the Stevens Institute of Technology. His books include *The End of Science* and *The End of War*.

Drug tales are often tedious, but Pollan's accounts of his trips are my favorite parts of his book. He doesn't see the God he doesn't believe in, but he is fascinated by what happens to his self. "Of all the phenomenological effects that people on psychedelics report," he writes, "the dissolution of the ego seems to me by far the most important and therapeutic."

We see ourselves and the world more clearly, Pollan suggests, as our fears, desires and self-absorption diminish. (Wright, in *Why Buddhism Is True*, makes the same claim about meditation.) Pollan felt more compassionate and attuned to nature's wonders after his trips, and less anxious about death. "After a month or so, it was pretty much back to baseline," he adds with typical candor. "But not quite, not completely." He can recapture feelings of self-transcendence in meditation, and he realizes that "the mind is vaster, and the world ever so much more alive, than I knew when I began."

His trips, plus the growing peer-reviewed literature, have convinced Pollan that psychedelics can help the mentally troubled and enhance the lives of the healthy. Toward the end of his book, he reports on a psychedelic-research meeting attended by Thomas Insel, former head of the National Institute of Mental Health. Insel was impressed by evidence of psychedelics' mental-health benefits but warned researchers, "Don't screw it up!"

Pollan seems to have taken this message to heart. He could have derailed the psychedelic movement by being too critical or evangelical, so he finds a sensible middle ground between these extremes. He recommends not total legalization but a regime in which people take psychedelics with a trained guide. This is essentially the same scheme I advocated in 2003.

Like Pollan, I hope to see the day when people can take psychedelics safely and legally, especially given the limits of current treatments for mental illness. I nonetheless have misgivings about the popularization of psychedelics, misgivings that I suspect Pollan shares. Here they are:

*Just as most meditation researchers believe in meditation, so most psychedelic researchers believe in psychedelics. In other words, psychedelic science, like most fields, is rife with bias (although probably less than, say, psychiatric-drug research funded by the pharmaceutical industry).

*Far from making you wiser and nicer, psychedelics can make you an arrogant, narcissistic jerk. It can be hard distinguishing an ego that has vanished from one that has expanded to infinity. As Pollan notes of Timothy Leary, "It is one of the many paradoxes of psychedelics that these drugs can sponsor an ego-dissolving experience that in some people leads to massive ego inflation." This problem plagues Buddhism and other spiritual paths, too.

I spent a lot of time hanging out with psychedelicists while researching *Rational Mysticism* and for a while thereafter. I started pulling back from this community because some members struck me as self-righteous zealots. And as Pollan points out, psychedelics boost suggestibility—or, to put it less kindly, gullibility, which means that trippers are susceptible to bizarre claims, such as apocalyptic predictions.

*As William James notes in *The Varieties of Religious Experiences*, mystical experiences can be hellish as well as heavenly. After a wild trip in 1981, I suffered from depression and frightening flashbacks for months. Supervision can't eliminate the risk of hellish trips. As I note in *Rational Mysticism*, in the early 1990s psychiatrist

Rick Strassman injected DMT into 60 volunteers, and almost half experienced "adverse effects," including terrifying hallucinations of "aliens" that took the shape of robots, insects or reptiles. [See *Addendum*.]

Why, given these misgivings, did I take ayahuasca recently? Well, I just finished a book on the mind-body problem (which I plan to self-publish online soon), and I've been feeling restless. I wanted a jolt, something to knock me out of my cognitive rut. My best trips have helped me see—really *see*—life's jaw-dropping improbability, which I like to call "the weirdness." I wanted to glimpse the weirdness again. When I heard about a local ayahuasca session, I signed up.

We were a diverse bunch, black and white, young and old, male and female. At the beginning of the session, we expressed our hopes for the evening. We wanted to heal old wounds, to feel less fear and anger and self-loathing and more happiness and love.

I had moments of what might be called transcendence, during which the world seemed heartbreakingly beautiful. My strongest emotion was pity for those retching and moaning around me, and for all humanity. I thought, Look at how far we go just to find a little happiness! We live in paradise, but we can't *see* it, because we're so trapped in our petty schemes and troubles.

But these feelings lacked force. They seemed familiar, even trite, like postcards from old trips. Within a few days, I was as self-absorbed as ever. I think I've gotten what I can from psychedelics, so I'm going to try something more dramatic, a silent meditation retreat. No talking for eight days, no phone, laptop, email, Twitter, Facebook, Kindle, *New York Times*. I'm much more nervous than I was before my ayahuasca session. My digital self feels more real to me lately than my flesh-and-blood self. When I'm disconnected from the Internet, will I still exist?

Addendum: Strassman has accused other researchers of inappropriately downplaying psychedelics' risks. See for example his stinging review of a 2016 book by psychologist William Richards, who is associated with psychedelic research at Johns Hopkins. Strassman writes: "It is important to refrain from glorifying the psychedelic drug state. Simply look at how Charles Manson used LSD's meaning-enhancing effects in those similarly predisposed to particular goals and aspirations (Bugliosi, 1994). Just as important, Richards seeks to render their adverse effects innocuous. Contrary to the universal practice of excluding prepsychotic or formerly psychotic individuals from psychedelic drug administration studies, he casually suggests that psychedelics may actually help such people. Psychedelics may hasten their entry into treatment (through precipitating a psychotic break?) or prevent psychosis through uncovering relevant psychic conflicts (p. 185)." M

YUICHIRO CHINO *GETTY IMAGES*

OPINION

What Your Facebook Network Reveals about How You Use Your Brain

If your friends mostly know each other only indirectly, through you, you're likely to be a better problem solver and to be more successful overall

By Emily Falk and Michael Platt

If I asked you roughly how many Facebook friends or Twitter followers you have, you might be able to give me a good answer. But what about the *shape* of your social network? For example, do the friends in your social network know each other independently or are they only indirectly connected through you?

Decades of research have shown that having more numerous and stronger connections predicts better health and well-being, but the shape of your social network matters too. People who are "information brokers" connect people who wouldn't otherwise know each other. Think of the character "Finn" on *Glee*, who as a football player who also sings serves as a bridge between two different worlds; or someone you work with who knows people from every department who don't all know each other. At workplaces, Ronald Burt and his colleagues have shown, information brokers come up with better solutions to problems, potentially because they are exposed to more diverse perspectives.

They also receive faster promotions and higher pay. More broadly, being a good friend, teacher or manager often requires taking the perspective of others—seeing the world through their eyes and understanding their joys and sorrows. These capacities depend on a social brain network, which is a neural circuit activated when we connect with others. A new series of studies shows that the structure and function of your social brain network is tied to the structure of your social network.

In one study, we asked teens (with their parents' permission) to give us access to their list of Facebook friends. This allowed us to see whether teens who are information brokers use their social brain networks differently than teens whose friends all know one another. We scanned their brains while they made social decisions (about whether to recommend different products to their peers). We found that information brokers use their social brain networks more when making choices about what to recommend to others than people whose friends all know one another.

This may come about because information brokers have more opportunities to practice using their social brain when translating ideas between different groups of people. More broadly, people who are better at selling their ideas, literally and figuratively, also tend to engage these brain regions more than people who are less successful. Considering another individual's point of view more deeply (for example, what will the person I'm going to share with think about this idea?) helps the sharer tune her message to resonate more clearly with the mental state of the listener.

Genetic studies in people and monkeys indicate that the brain hardware supporting social interactions is at least partially inherited. Although the tendency to be social is hardwired into us, our genes are not our destiny. Studies of monkeys also show that the social brain network responds like a muscle as a function of use. When monkeys are

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Michael Platt is the James S. Riepe Penn Integrates Knowledge university professor of neuroscience, marketing, and psychology and director of the Wharton Neuroscience Initiative at the University of Pennsylvania. He studies decision making and social interaction using tools from neuroscience, psychology, economics and anthropology.

forced to navigate a larger social network, their social brain networks increase in size and connectivity. This in turn confers a greater capacity to network with others.

The idea that social brain networks expand with use is an important insight to consider in educational and workplace contexts. These observations suggest that providing access to wider and more diverse networks of social ties may fundamentally change the way people use their brains when making day-to-day decisions. Even earlier in life, research by Cornell University psychologist Katherine Kinzler's team shows that toddlers and young children who are raised around people speaking multiple languages—and hence who may have more practice keeping track of different perspectives like who can understand whom—performed better on a task that required perspective taking, compared to kids raised in monolingual environments.

As people change the way they use their brains during social interactions, this can also have ripple effects on others. When people communicate, they influence the ways that their conversation partners see the world. For example, work by Princeton University psychologist Uri Hasson's team shows that the more activity an idea sparks in one individual's social brain network, the more that person tends to elicit similar activity in the social brain networks of others when they communicate. When this happens the two brains become more in sync (that is, show coordinated patterns of activity while the speaker speaks and the listener listens), and the more in sync their brains become, the more successful their communication.

As people change the way they use their brains during social interactions, this can also have ripple effects on others.

Most people are born with a high-performance neural toolkit that drives their desire to connect with others and their ability to understand their thoughts and feelings, but learning how to use the tools is critical both for students and for relationships at work, at school and at home. This toolkit has deep evolutionary roots and is fundamental to who we are as a species.

Understanding the biology of how people connect may also provide practical benefits, for example by identifying new ways to boost students' curiosity and engagement in school, select people for teams, monitor employee onboarding and fit with corporate culture, and identify and cultivate more effective leaders. It may also help us to develop new ways to reduce loneliness—a major contributor to health problems ranging from heart disease to the current opioid epidemic—and thereby improve health and well-being.

As we look ahead and consider ways to offset the current climate of political tribalism and disconnection, the science of social connection is more relevant than ever. **M**

OPINION

Why We Need to Take Pet Loss Seriously

How to handle grief after a pet's death—and why we all need to change our attitudes about it

By Guy Winch

CHRISTIN LOLA *GETTY IMAGES*

Doug's amateur soccer team had just lost its playoff game and he needed a pick-me-up. So he decided to stop by the local animal shelter on his way home. He was by no means looking to adopt an animal, but puppies always put a smile on his face. "Rookie mistake," he told me in our psychotherapy session. "You set foot in one of these places and no way you're not leaving with a puppy." Delia, the puppy in question, was a five-month-old mutt. "I had her for seventeen years," Doug said, wiping tears from his eyes, "Almost my entire adult life. I knew it would be rough when she died but I had no idea…I was a total wreck. I cried for days. I couldn't get any work done. And worst of all, I was too embarrassed about it to tell anyone, even my old soccer teammates who loved Delia. I spent days at work crying in private and muttering "allergies" whenever someone glanced at my puffy eyes."

Guy Winch is a psychologist, speaker and author. His books have been translated into 25 languages and his two TED Talks have been viewed over 10 million times. His new book, *How to Fix a Broken Heart* (TED Books/Simon & Schuster, 2018), covers both pet loss and romantic heartbreak.

Losing a beloved pet is often an emotionally devastating experience. Yet, as a society, we do not recognize how painful pet loss can be and how much it can impair our emotional and physical health. Symptoms of acute grief after the loss of a pet can last from one to two months with symptoms of grief persisting up to a full year (on average). *The New England Journal of Medicine* recently reported that a woman whose dog died experienced Broken Heart Syndrome—a condition in which a person's response to grief and heartbreak is so severe, they exhibits symptoms that mimic a heart attack, including elevated hormone levels that can be 30 times greater than normal.

While grief over the loss of a cherished pet may be as intense and even as lengthy as when a significant person in our life dies, our process of mourning is quite different. Because pet loss is disenfranchised, many of the societal mechanisms of social and community support are absent when a pet dies. Few of us ask our employers for time off to grieve a beloved cat or dog as we fear doing so would paint us as overly sentimental, lacking in maturity or emotionally weak. And few employers would grant such requests were we to make them. Studies have found that social support is a crucial ingredient in recovering from grief of all kinds. Thus, we are not only robbed of crucial support systems when our pet dies, but our own perceptions of our emotional responses are likely to add an additional layer of emotional distress. We may feel embarrassed and even ashamed about the severity of the heartbreak we feel and consequently, hesitate to disclose our distress to our loved ones. We might even wonder what is wrong with us and question why we are responding in such "disproportional" ways to the loss.

Feeling intense grief that is then layered with shame about these feelings not only makes pet loss a bigger threat to our emotional health than it would be otherwise, it complicates the process of recovery by making it more lengthy and complex than it should be.

Further, given our societal attitude that invokes responses such as "It's just an animal" and "You can just get another one" we are likely to overlook the variety of ways our lives are impacted by pet loss (both real, practical and psychological), which can blind us to steps we need to take in order to recover. Losing a pet can leave significant voids in our life that we need to fill: It can change our daily routines, causing ripple effects that go far beyond the loss of the actual animal.

For example, whether they are trained to or not, all pets function as therapy animals to some extent. Cats, dogs, horses and other cherished pets provide companionship, they reduce loneliness and depression and they can ease anxiety. Thus when we lose them we actually lose a significant and even vital source of support and comfort.

Caring for our pet also lets us develop routines and responsibilities around which we often craft our days. We get exercise by walking our dog and we socialize with other dog owners at the dog runs/parks/beaches. When our dog dies we might experience a significant drop in casual social interaction and feel left out of the unofficial community of dog owners to which we belonged. We awake early every day to feed our cat (or we are woken by them if we forget), but we get a lot more done because of it. Without our cat we might experience a real drop in productivity. Or we spend hours over the weekend out of the city so we can ride our horse, and find ourselves going stir crazy when our horse is no longer around. Losing a pet thus disrupts established routines that provide us with structure, support our emotional well-being and give our actions meaning. This is why, in addition to emotional pain, we feel aimless and lost in the days and weeks after our pet dies.

Lastly, we often consider ourselves parents to our pets and are even known as such in our communities. Everyone who owns a dog knows that neighbors on the street are far more likely to know our dog's name than they are to know ours. When our dog dies we can become invisible and lose a meaningful aspect of our identity. We post images and videos of our animals on social media and are followed for that reason. Losing a pet can impact many aspects of our own identities.

Recovering from pet loss, as in all forms of grief, requires us to recognize these changes and find ways to address them. We need to seek social support from people we know will understand and sympathize with our emotional pain and not judge us for it. Our best bet is to reach out to people we know who have also lost pets, as they are likely to understand our anguish and offer the best support. Many animal clinics offer bereavement groups for pet owners.

We also need to fill the voids the loss has created in our lives, and there are more of them than we might realize. We might need to reorganize our routines and daily activities so we don't lose the secondary benefits we derived from having our pet. For example, if our exercise came from walking our dog we need to find alternative ways to reach our daily "step goals." If our social media reach was built on our cat's starring Instagram popularity we need to find other ways to remain relevant social-media wise. If we spent most Saturday mornings with our Vizsla meetup group, we need to find other outlets through which we can socialize and enjoy the outdoors. If we were known in our neighborhood as "Delia's dad" as Doug was, we need to find other ways of feeling connected and involved in our community.

Doug suffered far more than he should have because of the shame and isolation he experienced. It's time we gave grieving pet owners the recognition, support and consideration they need. Yes, it is up to us to identify and address our emotional wounds when our pet dies, but the more validation we received from those around us, the quicker and the more complete our psychological recovery would be. M

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