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**MIND**

**The  
World  
Returns**

**After a year of  
living cautiously  
and more isolated,  
here's how to resume  
public routines**

**PLUS**

**BRILLIANT  
PROBLEM-  
SOLVING  
STRATEGIES**

**A WAVE OF  
PANDEMIC  
GRIEF IS ON  
ITS WAY**

**WHY DO  
PEOPLE IN  
RELATIONSHIPS  
CHEAT?**

WITH COVERAGE FROM  
**nature**

FROM  
THE  
EDITOR



liz tormes

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# The Quiet after the Storm

In mid-May the Centers for Disease Control and Prevention released new guidelines stating that fully vaccinated people were not required to wear masks in most settings, including indoors at restaurants and in other public spaces. The decision was soundly rooted in science, although it felt jarring to many—even those of us writing and reporting about COVID-19 on a daily basis. After more than a year of masks and social distancing, the idea of overnight returning to mostly normal was a shock to the system. We were not alone. A substantial number of individuals recently told researchers with the American Psychological Association that they were hesitant to resume to their old ways of life despite being vaccinated, as Melba Newsome reports in this issue's cover story (see "'Cave Syndrome' Keeps the Vaccinated in Social Isolation"). Personally, trusting the science and the effectiveness of the vaccines, in terms of both preventing severe disease (even from variants) and transmitting the virus to others, has given me the comfort to get back out there.

For those of us lucky enough to live in a country where case numbers keep declining, the aftereffects of the pandemic are coming into focus. After nearly 600,000 have died, millions in the U.S. have lost a loved one, and the grief has only just begun to set in (see "Covid Has Put the World at Risk of Prolonged Grief Disorder"). For those of us looking to finally walk out the door and face the world and for people coming to terms with the devastation of loss, time and self-compassion are in order.

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### On the Cover

After a year of living cautiously and more isolated, here's how to resume public routines

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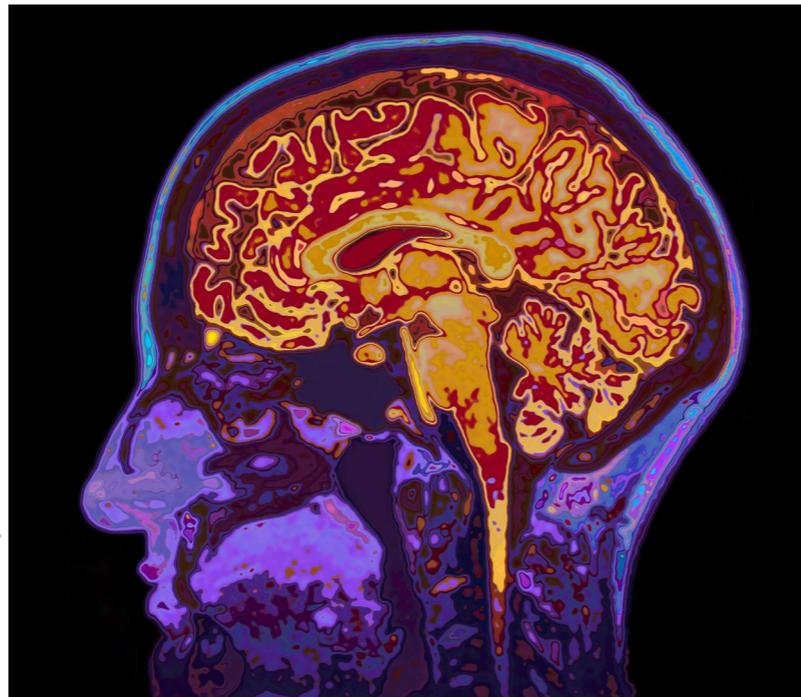
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## Students Who Gesture during Learning “Grasp” Concepts Better

Hand movement appears to help in teaching about statistical models

When we talk, we naturally gesture—we open our palms, we point, we chop the air for emphasis. Such movement may be more than superfluous hand flapping. It helps communicate ideas to listeners and even appears to help speakers think and learn.

A growing field of psychological research is exploring the potential of

having students or teachers gesture as pupils learn. Studies have shown that people remember material better when they make spontaneous gestures, watch a teacher’s movements, or use their hands and arms to imitate the instructor. More recent work suggests that telling learners to move in specific ways can help them

learn—even when they are unaware of why they are making the motions.

One study involved people who were asked to swing their arms or to stretch them—both groups were told the motion was to get blood flowing. The researchers found that those who swung their arms were more likely to solve a puzzle that required

a specific insight: to connect two strings hanging from the ceiling that were too far apart to reach at the same time, they needed to attach a weight to one to turn it into a pendulum. The blood-flow ruse worked: only three participants suspected a relationship between swinging or stretching their arms and solving the task. Apparently, this type of instructed movement helps thought even without any conscious connection to what a person is doing.

New work by researchers at the University of California, Los Angeles, and California State University, Los Angeles, extends this finding. “We’re trying to test ‘Where is the boundary of the power of gesture?’” says Icy (Yunyi) Zhang, a psychology graduate student at U.C.L.A. and the paper’s lead author. The researchers set about doing this by testing instructed hand movements’ subconscious effects on learning an abstract concept in statistics.

In the first of two experiments, reported in the February issue of *Cognitive Science*, 60 undergraduates came to a laboratory to stand and watch a brief narrated video. The video explained the idea of a statistical model, a function that generates

predictions. It depicted data as the bars of histograms and models as the means, or averages, of the data. (The simplest model of a collection of numbers is its mean.) Study participants were divided into three groups. A control group simply watched the video. A “match” group watched the same video overlaid with an animation. For the latter group, when the narrator said, for example, that one data set had more variation than another—represented by histograms with more bars placed along their  $x$  axis—two vertical red bars (unrelated to the histogram bars) moved away from each other. Those participants were asked to imitate the movement of the red bars with their hands, holding them vertically and moving them apart. A “mismatch” group was instructed to imitate red bars that moved in ways incongruous to the lesson. During the description of variation, for example, they were horizontal and moved vertically.

After watching the video three times, all participants took a short quiz. The match group outperformed the mismatch group, 16.3 to 12.6 (out of a maximum score of 23) on average, and the control group registered an in-between score.

## “We’re trying to test ‘Where is the boundary of the power of gesture?’”

—*Icy (Yunyi) Zhang*

A second experiment reproduced the results with 130 college students, this time sitting at laptops. Match participants scored 4.4 out of five points on average, outperforming both the control group (four points) and the mismatch group (3.8).

“It’s a nice, clean demonstration” of movement’s benefits, says Martha Alibali, a psychologist at the University of Wisconsin–Madison, who studies gesture in education and was not involved in the study. A model, she says, is “a super important concept, a really foundational statistical concept.”

“I like the fact that [the field] is moving into this new domain of statistics,” says Susan Goldin-Meadow, a psychologist at the University of Chicago, who has done extensive work on gestures but was also not involved in the study.

One question that was not tested is whether simply watching the matched animation could help performance as much as imitating it. Zhang doesn’t believe so, citing previous work

showing that gesturing holds benefits over watching animations.

The researchers had not revealed the goal of the experiment to the students. They hid their intent by telling the subjects a cover story, saying the study focused on multi-tasking. Afterward they asked the students to guess its real purpose. Of those who gestured, only about a third in the match group and a fifth of those in the mismatch group surmised the study had something to do with enhancing learning through gestures. Even when excluding the students who caught on to the purpose of the study, those in the group that performed matched movements were still helped by the exercise. Goldin-Meadow calls this aspect of the study “a really nice, interesting result.”

The instructed movements’ unconscious effects impressed Zhang. “It definitely convinced me of the power of embodied cognition,” the idea that physical interaction with our

surroundings influences even abstract thinking in ways we don't always recognize, she says.

There is one more benefit to gesturing: keeping learners engaged. The students rated how well they understood the video after each of the three viewings. Those in the two hand-movement groups gave higher ratings each time. The control group's ratings, however, declined about 20 percent from the second to the third viewing—possibly because of frustration at having to watch the video again rather than reduced understanding. The movement required of the other groups may have kept them absorbed.

Some teachers in the classroom have already been using movement as a learning tool. Alibali notes that in students her daughter's algebra class did "slope aerobics," getting out of their seats and moving their arms to represent various functions. Zhang says her work has the potential to be applied in teaching any lesson that includes a spatial component and that it could be adapted to classrooms or online learning. "I think gesture is used in the classroom all the time," Goldin-Meadow says, "so we might as well be using it well."

—Matthew Hutson

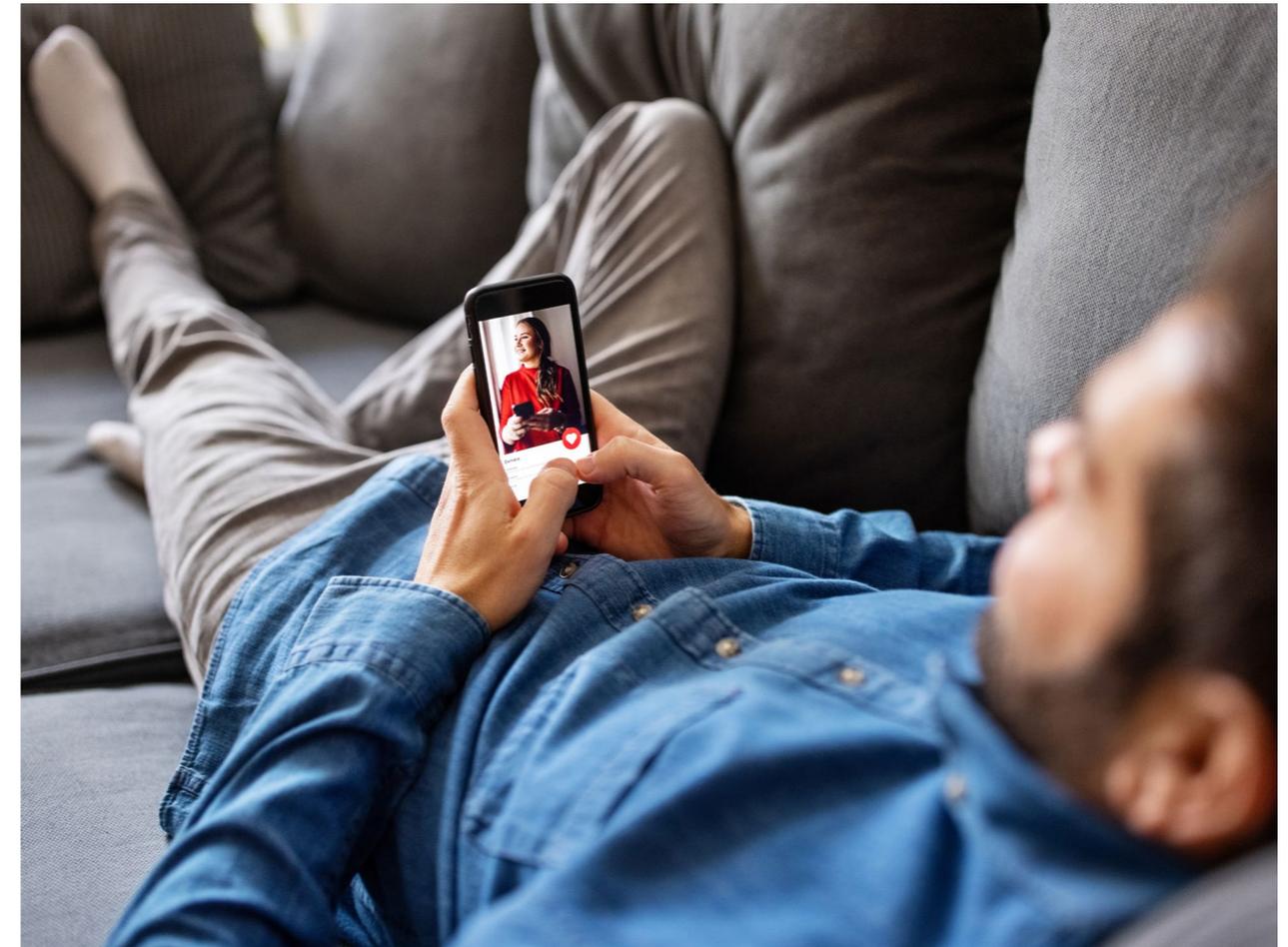
## Why Do People in Relationships Cheat?

A new study breaks down the reasons—they're complicated

Cheating: it's the ultimate relationship violation and a notorious relationship killer. A favorite gossiping pastime, the phenomenon is frequently discussed but difficult to study. The goal is to avoid getting caught, so why confess infidelity in the name of science?

But scientists can offer us new insight on a topic often shrouded in stigma and mystery. As researchers have recently demonstrated, cheating is rarely a simple affair. There are many reasons why people cheat, and the patterns are more complex than common stereotypes suggest. A fascinating new study sheds some light on these motivations.

The investigation included 495 people (87.9 percent of whom identified as heterosexual), who were recruited through a participant pool at a large U.S. university and through Reddit message boards with relationship themes. The participants



admitted to cheating in their relationship and answered the question at the root of the mystery: Why did you do it? An analysis revealed eight key reasons: anger, self-esteem, lack of love, low commitment, need for variety, neglect, sexual desire, and situation or circumstance. These motivations not only influenced why people cheated but how long they did so, their sexual enjoyment, their emotional investment in the affair

and whether their primary relationship ended as a result.

Though most cheating involves sex, it is rarely just about sex itself. Most participants felt some form of emotional attachment to their affair partner, but it was significantly more common in those who reported suffering from neglect or lack of love in their primary relationship. Around two thirds of participants (62.8 percent) admitted to expressing

affection toward their new partner. And about the same proportion (61.2 percent) engaged in sexually explicit dialogue with them. Roughly four out of 10 (37.6 percent) had intimate conversations, while one in 10 (11.1 percent) said, “I love you.” Those who reported feeling less connected to their primary partner experienced greater emotional intimacy in the affair, perhaps as a way of fulfilling that need. Similarly, when infidelity was linked to lack of love, individuals found the experience more intellectually and emotionally satisfying.

Participants’ satisfaction with sex differed depending on the reason for their affair. People reported feeling more sexually fulfilled when they cheated because of desire, lack of love or a need for variety. Those who cited a situation as the primary cause were far less satisfied. Much of the sexual activity was limited to kissing (86.7 percent) and cuddling (72.9 percent). In fact, the study found that only half of the cheaters reported having vaginal intercourse.

The reason for the infidelity also greatly impacted its length. In some cases, the relationship was a brief tryst, while others were a longer and deeper attachment. Those who

cheated because of anger (such as a wish to “seek revenge”), lack of love or need for variety had a longer affair, while those motivated by the situation (such as those who were “drunk” or “overwhelmed” and “not thinking clearly”) ended it earlier. Women also had a longer affair on average than men.

In the end, only a third of participants ultimately admitted the cheating to their primary partner. Women were more inclined to fess up than men. Those who came clean were more likely to have cheated out of anger or neglect rather than sexual desire or variety. This suggests that their confession was possibly a form of retribution and a way to exact revenge instead of a way to clear their conscience. The participants who confessed were also more likely to form a committed relationship with the affair partner.

While infidelity is typically a clandestine enterprise, some cheaters were less careful than others, perhaps intentionally. Those cheating because of lack of love went on more public dates and displayed more public affection toward their partner. PDA was also common for those seeking variety or looking to

boost their self-esteem. On the other hand, situational cheaters were less inclined to cheat out in the open, perhaps because they hoped to return to their primary relationship without getting caught.

So is an affair really a relationship killer? Ultimately, the fate of the participants’ primary relationship depended less on the act itself and more on what motivated it. Cheating was more likely to end a relationship when it arose from anger, lack of love, low commitment or neglect. And it was less likely to do so when the infidelity was circumstantial. Surprisingly, only one in five (20.4 percent) of relationships ended because of the affair. The same number of couples (21.8 percent) stayed together despite their primary partner finding out, while slightly more (28.3 percent) stayed together without their partner discovering their infidelity. The remaining relationships broke up for noncheating reasons.

Rarely did infidelity lead to a real relationship. Only one out of 10 of the affairs (11.1 percent) ultimately turned into a full-fledged commitment—one of the preconceptions that turns out to be true.

—Gary W. Lewandowski, Jr.

## New Brain Implant Turns Visualized Letters into Text

The technology lets people with paralysis perform thought dictation at rates approaching the thumb speeds of texters

When we move, sense or speak—or do just about anything—our brain generates a specific pattern of electrical activity. And for decades, scientists have been connecting those impulses to machines, not only to understand and treat brain diseases but also to help people with disabilities. Brain-computer interfaces, or BCIs, can restore movement in people with paralysis and may help treat neurological and psychiatric diseases.

The next frontier in BCIs may be things like the lowly text message; typing still poses maddeningly difficult challenges to bioengineers. A study published in May in *Nature* reports on a brain implant that will allow people with impaired limb movement to communicate with text formulated in their mind—no hands needed.

Developed by a team at Stanford

University, the artificial intelligence software, coupled with electrodes implanted in the brain, was able to “read” the thoughts of a man with full-body paralysis as he was asked to convert them to handwriting. The BCI transformed his imagined letters and words into text on a computer screen—a form of “mental handwriting.” The technology could benefit the millions of people worldwide who are unable to type or speak because of impaired limbs or vocal muscles.

Previous work by co-senior study author Krishna Shenoy of Stanford had helped analyze the neural patterns associated with speech. It also decoded imagined arm movements so that people with paralysis could move a cursor ploddingly on a keyboard screen to type out letters. But this technique only allowed them to type around 40 characters per minute, far lower than the average keyboard typing speed of around 190 characters per minute.

Shenoy’s team’s new work focused on imagined handwriting as a way to improve the speed of communication for the first time. And the researchers hope it will reach, at very least, smartphone texting rates. Their technique



allowed the study subject, who was 65 years old at the time of the research, to mentally type 90 characters per minute. That rate is not far from average for most senior texters, who can typically type around 115 characters per minute on a phone.

“This line of work could help restore communication in people who are severely paralyzed, or ‘locked-in,’”

says Frank Willett, lead author of the paper and a research scientist at Stanford’s Neural Prosthetics Translational Laboratory. “It should help people express themselves and share their thoughts. It’s very exciting.”

The study participant suffered a spinal cord injury in 2007 and had lost most movement below his neck. In 2016 Stanford neurosurgeon

Jaimie Henderson, co-senior author of the paper, implanted two small BCI chips into the patient’s brain. Each of the chips had 100 electrodes capable of sensing neuronal activity. They were implanted in a region of the motor cortex that controls movement of the arms and hands, allowing the researchers to profile brain-activity patterns associated with written language.

“This study is an important and clear advance for intracortical brain-computer interfaces,” says Amy L. Orsborn, a member of the department of bioengineering at the University of Washington. “One obvious reason why is because they achieved a huge leap in performance on a challenging but important task like typing. It’s also the most significant demonstration to date of leveraging established tools in machine learning like predictive language models to improve BCIs.”

“I saw this research initially presented at a poster in 2019 and think it’s great,” says Mijail D. Serruya, an assistant professor of neurology at Thomas Jefferson University, who studies BCIs in stroke recovery but was not involved in the research. “I think it clearly shows that fine motor

trajectories can be decoded from neocortical activity.”

Serruya adds that his research could align with Willett’s in helping to treat people who have suffered brain trauma or a stroke. “We have shown that motor control signals can be decoded [following a stroke], implying that some of the decoding approaches developed by Willett might have applications beyond people with spinal cord injury,” he says.

Yet Serruya also has one quibble with the new research—a hesitation he posed to Willett a few years ago: he believes that while focusing on restoring communication via written letters is intuitive, it may not be the most efficient means of doing so.

“Why not teach the person a new language based on simpler elementary gestures, similar to stenography chords or sign language?” Serruya asks. “This could both boost the speed of communication and, crucially, decrease the mental effort and attention needed.”

But for now, Willett is focused on mentally decoding our more familiar forms of communication—and he wants to repeat the typing experiment with other paralyzed people. He explains that while translating the

brain’s control over handwriting is a significant first step in reclaiming someone’s ability to communicate, decoding actual speech—by analyzing what someone intends to say—is still a major challenge facing researchers, given that we generate speech much more quickly than we write or type.

“It’s been a hard problem to decode speech with enough accuracy and vocabulary size to allow people to have a general conversation. There’s a much higher signal-to-noise ratio, so it’s harder to translate to the computer,” Willett says. “But we’re now excited that we can decode handwriting very accurately. Each letter evokes a very different pattern of neural activity.”

As for when text-and-speech-decoding technology might be available to the public, Willett is cautiously optimistic. “It’s hard to predict when our method will be translated into a real device that anyone can buy,” he admits. “Of course, we hope it will be soon, and there are companies working on implantable BCI devices now. But you never know when someone will succeed in translating it. We hope it’s within years and not decades!”

—Bret Stetka

## Psilocybin Therapy May Work as Well as a Common Antidepressant

**For the first time, a randomized controlled trial shows the psychedelic offers potent, if short-term, relief in comparison with an SSRI**

The first randomized controlled trial to compare the illicit psychedelic psilocybin with a conventional selective serotonin reuptake inhibitor (SSRI) antidepressant found that the former improved symptoms of depression just as well on an established metric—and had fewer side effects. The study was fairly small, however, and was not explicitly intended to show how well the drugs stacked up on other measures of well-being.

In a study published in April in the *New England Journal of Medicine*, psychiatrist David Nutt, psychologist Robin Carhart-Harris and other researchers, all then at Imperial College London, conducted a six-week trial of 59 participants split into two groups. One group was

given a full dose of psilocybin (the active ingredient in “magic mushrooms”) in combination with psychotherapy. The other received daily amounts of the SSRI escitalopram plus two minuscule amounts of psilocybin with psychotherapy. All of the participants suffered from major depressive disorder (MDD), which affects roughly 10 percent of the U.S. population in a given year.

Researchers had previously conducted an open-label trial (in which subjects and practitioners know which treatment they are getting) and four randomized controlled trials of psilocybin for depression and anxiety. But until now, no randomized controlled trials had directly compared psilocybin with an SSRI.

“Conventional antidepressants have dominated psychiatry for so long, so it is noteworthy to compare psilocybin—still an illegal drug—with a standard first-line treatment,” says Carhart-Harris, now at the University of California, San Francisco’s Neuroscape center. Psilocybin is designated as a Schedule I substance, defined as having “no currently accepted medical use and a high potential for abuse.” “This study clearly suggests we need

to change the legal status of psilocybin because it is starkly at odds with the data,” Carhart-Harris says.

The researchers used a variety of measures to score study subjects for depressive symptoms and employed the 16-point Quick Inventory of Depressive Symptomatology-Self-Report (QIDS-SR-16)—a self-assessment questionnaire—as the study’s primary outcome. The QIDS-SR-16 mean scores did not show a statistically significant difference between the group given psilocybin alone and the one given the SSRI after six weeks.

But the psilocybin group showed significantly larger reductions in suicidality, anhedonia (a lack of the ability to feel pleasure), and standard psychological scores for depression known as the Montgomery-Asberg Depression Rating Scale (MADRS) and the Hamilton Depression Rating Scale (HAM-D). In particular, Carhart-Harris notes, within the 16 items in the QIDS-SR-16 questionnaire, many of the differences were highly significant: 70 percent of subjects in the psilocybin group responded to the treatment, compared with 48 percent of those in the SSRI group. The difference in remission

rates was also statistically significant: the rate in the psilocybin group was 57 percent, and it was 28 percent in the escitalopram group.

“Looking at their data, it’s very clear to me that there is a substantial difference between those two groups in precisely the direction we would have predicted,” says Roland Griffiths, director of the Johns Hopkins Center for Psychedelic and Consciousness Research, who was not involved in this study but published his own “landmark” paper in *JAMA Psychiatry* last year: the first randomized controlled trial to examine psilocybin therapy for MDD.

“One of the most notable aspects of this new paper from Imperial [College London] is where it is being published, the *NEJM*, which is a marker for where mainstream medicine is situated,” says psychiatrist Charles Grob of the University of California, Los Angeles, who was also not involved in this study and has studied psilocybin and other psychedelics for decades. His most cited papers examined the psilocybin’s ability to reduce anxiety and improve quality of life in patients with terminal cancer. “This also indicates where we are as a society,” Grob says. “In 2006, when



Psilocybin, the active ingredient in “magic mushrooms,” may provide relief from depression symptoms that is equivalent to, or better than, an SSRI antidepressant.

we began recruiting for our studies on cancer, it was very challenging.” By comparison, the scientists conducting the new trial were overwhelmed with volunteers: they ultimately screened 1,000 people, of whom they selected only 59.

The team anticipated that this high number of “self-referrals,” most of whom experienced a strong preference for psilocybin over an SSRI, would likely influence the study’s outcomes, Carhart-Harris says. Those

who received escitalopram would probably express disappointment, and those receiving the psilocybin could improve even more than they would if the study had been conducted 10 years ago. Many factors make careful statistical scrutiny of psychedelic therapies difficult—and raise the question of whether “blinding” subjects to the treatment they receive is even possible with such strong psychoactive drugs.

The researchers attempted to

minimize this effect by telling people in both groups they would receive psilocybin to set up equivalent expectations. They gave both groups the standard experience of a psychedelic dosing: an extended, four- to six-hour session in which each subject was instructed to lie still while blindfolded and listening to music, with one or two therapists in the room for support. The participants assigned to the psilocybin group were given a 25-milligram dose of psilocybin for the full effect. Those in the escitalopram group were given a one-milligram subperceptual “microdose” with no obvious psychedelic effects. Finally, after the first dosing, the team gave every subject a bottle of pills and instructed them to take one per day: the escitalopram group received the SSRI, whereas those in the psilocybin group simply took a placebo.

“This is an incredibly exciting topic, but it does require very rigorous scientific methodology to really understand the safety and efficacy of these treatments,” says psychiatrist Gerard Sanacora, an associate professor at the Yale School of Medicine and director of the Yale Depression Research Program, who

was not involved in the study. This is a relatively small number of people with no placebo group, so we are limited in what conclusions we can draw from this data,” he says. “I look at this data as promising and warranting this study. But sometimes the excitement does get ahead of the science, so we need to be honest in saying what the limitations are.”

Sanacora also notes that the psychotherapeutic component of the study—which gave equal amounts of preparation, counseling and follow-up to both the escitalopram and psilocybin groups—is unusual and noteworthy. Every participant received between 38 and 40 hours of psychotherapy in total—roughly double the normal amount subjects in most psychedelic studies receive. “That kind of psychosocial intervention is really quite powerful,” he says.

“It’s really important for us to recognize that, in the study, both groups did well, and the reason they both did well is because there was so much care and attention in this study,” says psychologist Rosalind Watts, a co-author of the paper and lead of the clinical portion of the research. She is now a member of the advisory board at Synthesis, a center that

offers psychedelic therapy retreats in the Netherlands. That nation is one of the few jurisdictions where psilocybin (in the form of truffles) is legal. In Oregon, citizens voted in November 2020 to legalize psilocybin therapy for medical purposes.

The psychological component of psychedelic therapy tends to be underemphasized by both scientists and the media, yet it is thought to be integral to the therapy’s efficacy, Watts says—in particular because these experiences can be unsettling, powerful, confusing and even scary. The feeling of “safety” and an “alliance” with a therapist is often crucial for any psychological breakthrough. This is especially true for many patients with depression, who often lack confidence to try new treatments after many have failed.

“I thought the drug might work for some people but probably would not work for me. I was quite terrified because I didn’t really trust my brain; I felt like it was always working against me,” says Ali Thorne, a 32-year-old registered nurse in the U.K., who took part in the trial after suffering from depression for two decades. “I think the trial—both the psilocybin and the psychological support—really saved

my life.” (Following the study, participants were informed which treatment they had received.)

Yet while some of the subjects experienced enduring benefits after the trial concluded, others relapsed into depression. Leonie Schneider, a 44-year-old Greek woman living in England, was one of the participants who became depressed again, following a particularly challenging period of unfortunate events that included severe financial difficulties as a result of COVID and family members with a terminal illness. “I became more depressed than I’d been in my entire life, and it was even more difficult because I had come off the medication I had previously relied on prior to the trial. Plus, COVID was kicking off, and I didn’t have the stabilizing crutches I normally had to cope,” she says.

Schneider notes, however, that two decades of trying a multitude of SSRI antidepressants in addition to talk therapy did not give her the resilience she needed. “Antidepressants often just felt like a palliative care approach to mental health,” she says. In comparison, “the [psilocybin] trial gave me the tools to begin that work and build that emotional resilience.”

“While studies for somebody who is facing death and depressed due to terminal illness may show a lasting change from one session with psilocybin, if someone has been depressed for decades for no discernible reason, it is less likely to be alleviated with just one or two doses,” Watts notes.

When the trial ended in March 2020, as the COVID-19 pandemic was exploding, Watts and other members of the team set up online therapy sessions for trial participants who felt they needed extra support. Schneider was quick to sign up, as was Thorne, along with 16 other participants who have met regularly with the study psychologists and one another online for a year. This has extended the period known as “integration,” when individuals make sense of the visions and insights they felt under the influence of psilocybin.

“People describe psychedelic therapy as 25 years of therapy in one afternoon. And it can absolutely feel like that, but it’s not a silver bullet—and it’s just an afternoon,” Schneider says. “The real magic in this is not in the dosing day, it’s in the work that you do afterward.”

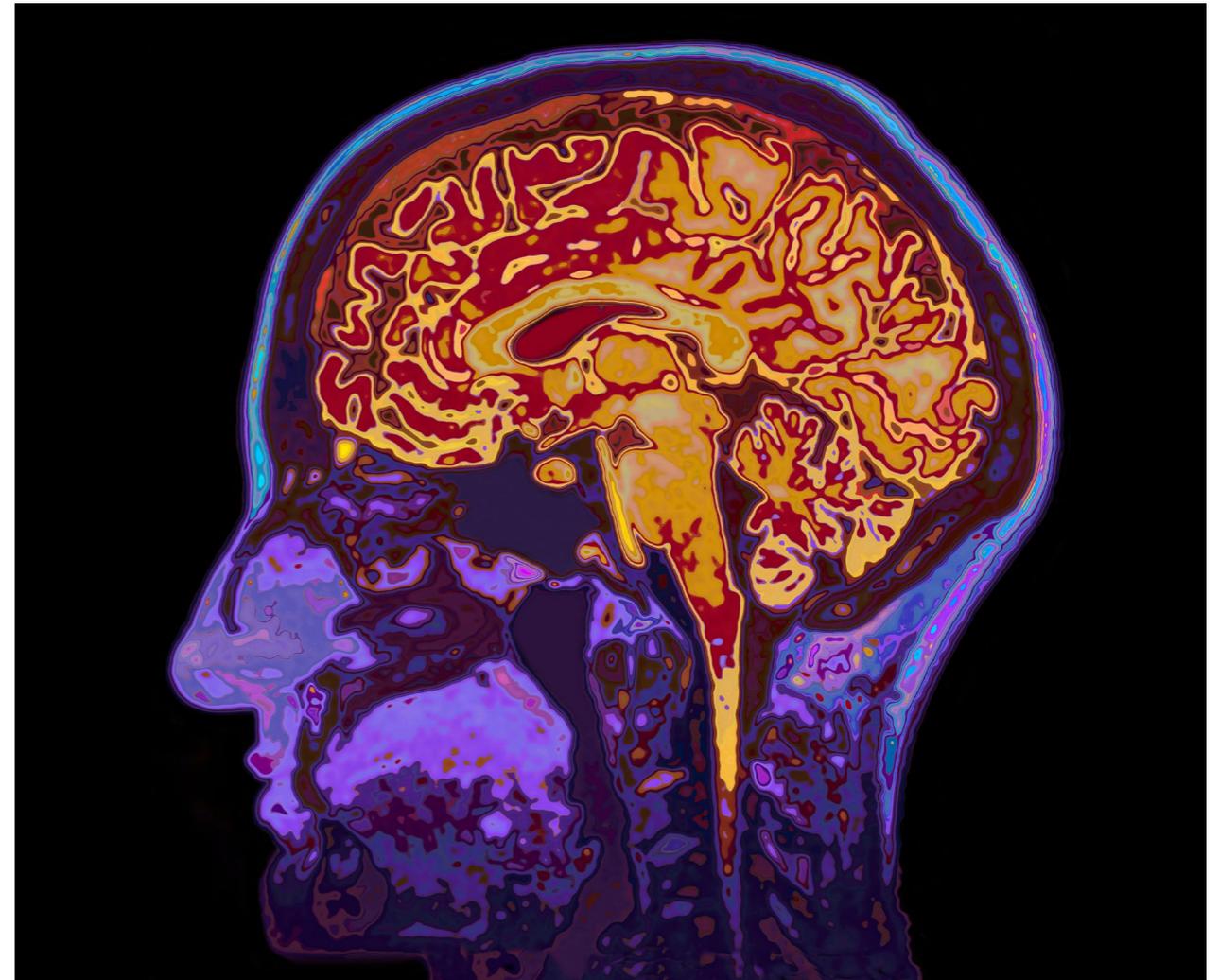
—Zoe Cormier

## Forgotten Memories of Traumatic Events Get Some Backing from Brain-Imaging Studies

A new wave of research seeks neurological signatures for a type of amnesia

When adults claim to have suddenly recalled painful events from their childhood, are those memories likely to be accurate? This question is the basis of the “memory wars” that have roiled psychology for decades. And the validity of buried trauma turns up as a point of contention in court cases and in television and movie story lines.

Warnings about the reliability of a forgotten traumatic event that is later recalled—known formally as a delayed memory—have been endorsed by leading mental health organizations such as the American Psychiatric Association (APA). The skepticism is based on a body of research showing that memory is unreliable and that simple manipula-



tions in the lab can make people believe they had an experience that never happened. Some prominent cases of recovered memory of child abuse have turned out to be false, elicited by overzealous therapists.

But psychotherapists who specialize in treating adult survivors of childhood trauma argue that laboratory experiments do not rule out the

possibility that some delayed memories recalled by adults are factual. Trauma therapists assert that abuse experienced early in life can overwhelm the central nervous system, causing children to split off a painful memory from conscious awareness. They maintain that this psychological defense mechanism—known as dissociative amnesia—

turns up routinely in the patients they encounter.

Tensions between the two positions have often been framed as a debate between hard-core scientists on the false-memory side and therapists in clinical practice in the delayed-memory camp. But clinicians who also do research have been publishing peer-reviewed studies of dissociative amnesia in leading journals for decades. A study published in February in the *American Journal of Psychiatry*, the flagship journal of the APA, highlights the considerable scientific evidence that bolsters the arguments of trauma therapists.

The new paper uses magnetic resonance imaging (MRI) to study amnesia, along with various other dissociative experiences that are often said to occur in the wake of severe child abuse, such as feelings of unreality and depersonalization. In an editorial published in the same issue of the journal, Vinod Menon, a professor of psychiatry and behavioral sciences at the Stanford University School of Medicine, praised the researchers for “[uncovering] a potential brain circuit mechanism underlying individual differences in dissociative symptoms in adults with

early-life trauma and PTSD [post-traumatic stress disorder].”

Milissa Kaufman is senior author of the new MRI study and head of the dissociative disorders and trauma research program at McLean Hospital, a teaching hospital affiliated with Harvard Medical School. She notes that, as with earlier MRI studies of trauma survivors, this one shows that there is a neurological basis for dissociative symptoms such as amnesia. “We think that these brain studies can help reduce the stigma associated with our work,” Kaufman says. “Like many therapists who treat adult survivors of severe child abuse, I have seen some patients who recover memories of abuse.”

Since 1980, dissociative amnesia has been listed as a common symptom of PTSD in every edition of the *Diagnostic and Statistical Manual of Mental Disorders (DSM)*—psychiatry’s diagnostic bible. The condition has been backed up not just by psychiatric case studies but by dozens of studies involving victims of child abuse, natural disaster, torture, rape, kidnapping, wartime violence and other trauma.

For example, two decades ago psychiatrist James Chu, then director of the trauma and dissociative

**“Like many therapists who treat adult survivors of severe child abuse, I have seen some patients who recover memories of abuse.”**

—*Milissa Kaufman*

disorders program at McLean Hospital, published a study involving dozens of women receiving in-patient treatment who had experienced childhood abuse. A majority of the women reported previously having partial or complete amnesia of these events, which they typically remembered not in a therapy session but while at home alone or with family or friends. In many instances, Chu wrote, these women “were able to find strong corroboration of their recovered memories.”

False-memory proponents have warned that the use of leading questions by investigators might seed an untrue recollection. As psychiatrist Michael I. Goode wrote of Chu’s study in a letter to the editor, “Participants were asked ‘if there was a period during which they “did not remember that this [traumatic] experience happened.”’ With this question alone, the actuality of the

traumatic experience was inherently validated by the investigators.”

MRI studies conducted over the past two decades have found that PTSD patients with dissociative amnesia exhibit reduced activity in the amygdala—a brain region that controls the processing of emotion—and increased activity in the prefrontal cortex, which controls planning, focus and other executive functioning skills. In contrast, PTSD patients who report no lapse in their memories of trauma exhibit increased activity in the amygdala and reduced activity in the prefrontal cortex.

“The reason for these differences in neuronal circuitry is that PTSD patients with dissociative symptoms such as amnesia and depersonalization—a group comprising somewhere between 15 and 30 percent of all PTSD patients—shut down emotionally in response to trauma,” says Ruth Lanius, a professor of psychiatry and

director of the PTSD research unit at the University of Western Ontario, who has conducted several of these MRI studies. Children may try to detach from abuse to avoid intolerable emotional pain, which can result in forgetting an experience for many years, she maintains. “Dissociation involves a psychological escape when a physical escape is not possible,” Lanius adds.

False-memory researchers remain skeptical of the brain-imaging studies. Henry Otgaar, a professor of legal psychology at Maastricht University in the Netherlands, who has co-authored more than 100 academic publications on false-memory research and who often serves as an expert witness for defendants in abuse cases, maintains that intact autobiographical memories are rarely—if ever—repressed. “These brain studies provide biological evidence just for the claims of patients who report memory loss due to dissociation,” he says. “There are many alternative explanations for these correlations—say, retrograde amnesia, in which the forgetting is due to a brain injury.”

In an effort to provide a firmer grounding for their arguments,

Kaufman and her McLean colleagues used artificial intelligence to develop a model of the connections between diverse brain networks that could account for dissociative symptoms. They fed the computer MRI data on 65 women with histories of childhood abuse who had been diagnosed with PTSD, along with their scores on a commonly used inventory of dissociative symptoms. “The computer did the rest,” Kaufman says.

Her key finding is that severe dissociative symptoms likely involve the connections between two specific brain networks that are active at the same time: the so-called default mode network—which kicks in when the mind is at rest and involves remembering the past and envisioning the future—and the frontoparietal control network—which is involved in problem-solving.

The McLean study is not the first attempt to apply machine learning to dissociative symptoms. In a paper published in the September 2019 issue of the *British Journal of Psychiatry*, researchers showed how MRI scans of the brain structures of 75 women—32 with dissociative identity disorder, for which dissociative amnesia is a key symptom, and

43 matched controls—could discriminate between people with or without the disorder nearly 75 percent of the time.

Kaufman says additional research needs to be carried out before clinicians can begin using brain connectivity as a diagnostic tool to assess the severity of dissociative symptoms in their patients. “This study is just a first step on the pathway to precision medicine in our field,” she says.

Richard Friedman, a professor of clinical psychiatry at Weill Cornell Medical College, considers the goal of the McLean researchers laudable. But he notes that the road ahead remains challenging and warns that the history of psychology is filled with “objective assessments” for a particular diagnosis or state of mind that never lived up to their hype. Friedman cites the case of lie-detector tests, in which false positives and false negatives abound.

While a brain-based test that could diagnose dissociative symptoms is not likely anytime soon, research on neurobiological explanations show the controversy over forgetting and remembering traumatic memories is far from settled. —Joshua Kendall

## Our Brain Typically Overlooks This Brilliant Problem-Solving Strategy

**People often limit their creativity by continually adding new features to a design rather than removing existing ones**

For generations, the standard way to learn how to ride a bicycle was with training wheels or a tricycle. But in recent years, many parents have opted to train their kids with balance bikes, pedalless two-wheelers that enable children to develop the coordination needed for bicycling—a skill that is not as easily acquired with an extra set of wheels.

Given the benefits of balance bikes, why did it take so long for them to replace training wheels? There are plenty of other examples in which overlooked solutions that involve subtraction turn out to be better alternatives. In some European cities, for example, urban planners have gotten rid of traffic lights and road

signs to make streets safer—an idea that runs counter to conventional traffic design.

Leidy Klotz, an engineer at the University of Virginia, noticed that minimalist designs, in which elements are removed from an existing model, were uncommon. So he reached out to Gabrielle Adams, a social psychologist at the university, to try to figure out why this was the case. The two researchers hypothesized that there might be a psychological explanation: when faced with a problem, people tend to select solutions that involve adding new elements rather than taking existing components away.

Adams, Klotz and their colleagues set out to test if their hunch was correct. “We wanted to investigate whether, and to what extent, people actually overlooked subtraction when they’re tasked with changing things,” Adams says. Their investigation “wasn’t literature driven, because there’s [no academic] literature on this phenomenon. It was really just us putting our heads together to think up why this might be the case.”

The researchers first carried out a set of observational studies, assessments without a control group, to see whether this bias existed at all. In



one, they asked 91 participants to make a pattern symmetrical by either adding or removing colored boxes. Only 18 people (20 percent) used subtraction. In another, the team scanned through an archive of ideas for improvement submitted to an incoming university president and found that only 11 percent of 651 proposals involved eliminating an

existing regulation, practice or program. Similar results emerged across tasks that involved modifying structures, essays and itineraries—in each case, the vast majority of people chose to augment rather than remove.

To determine why people tended to choose additive solutions, the team dug deeper by conducting a

series of eight experiments with more than 1,500 individuals recruited either from a university campus or through Amazon Mechanical Turk, a crowdsourcing Web site. In one experiment, people were asked to stabilize the roof of a Lego structure held up by a single block that rested atop a cube-shaped base. The reward for completing the task was

\$1, and participants could add new blocks for 10 cents apiece or get rid of blocks for free. The researchers wrote that one group was provided a cue about potential subtractive solutions by being told, “Each piece that you add costs ten cents but removing pieces is free,” while another group was just told, “Each piece that you add costs ten cents.” Almost two thirds of people in the cued group ended up choosing to eliminate the single block rather than adding new ones, compared with 41 percent of those who had not received the prompt.

The researchers also observed that people were more likely to remove features when they were given more opportunities to consider alternative ways to address a problem: when participants were asked to create a symmetrical pattern by adding or eliminating colored blocks, they opted for removal more often if they were given practice trials than if they had just one chance to tackle the problem. On the other hand, having to simultaneously juggle another task—such as keeping track of numbers on a

screen—made individuals less likely to subtract elements to solve the same problem, suggesting that it requires more effort to think up subtractive solutions than additive ones. (In both of these experiments, removing blocks was the more efficient solution.)

These findings, which were published in April in *Nature*, suggest that “additive solutions have sort of a privileged status—they tend to come to mind quickly and easily,” says Benjamin Converse, a social psychologist at the University of Virginia and a co-author of the study. “Subtractive solutions are not necessarily harder to consider, but they take more effort to find.”

The authors “convincingly demonstrate that we tend to not consider subtractive solutions as much as additive ones,” says Tom Meyvis, a consumer psychologist at New York University, who was not directly involved in the study but reviewed it and co-authored a commentary about it in *Nature*. While the propensity for businesses and organizations to opt for complexity rather than

simplification was previously known, the novelty of this paper is that it shows that people tend toward adding new features, “even when subtracting would clearly be better,” he adds. Meyvis also notes that other reasons for this effect may be a greater likelihood that additive solutions will be appreciated or the so-called sunk-cost bias, in which people continue investing in things for which time, money or effort has already been spent.

A number of open questions remain, such as whether the bias against subtractive solutions generalizes across cultures and if it exists in childhood or develops over time. For now the team hopes that these findings will encourage people across various fields, whether they be engineering, architecture or medicine, to think about subtractive options—such as balance bikes—that might be typically be overlooked. “The hope is that, just by getting people to think about this more, that maybe it will help inspire some other neglected subtractions,” Converse says.

— Diana Kwon

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# “Cave Syndrome” Keeps the Vaccinated in Social Isolation

After a year away from friends and co-workers,  
people sometimes struggle to resume  
their public routines

*By Melba Newsome*





**A**FTER BEING DIAGNOSED WITH COVID IN NOVEMBER 2020, Andrea King Collier doubted the antibodies that she had developed in response to the illness would protect her from a second infection and was determined to be first in, or near the front of, the line for a vaccine. The Flint, Mich., resident registered at every vaccine distribution site she could find and never stopped looking for a way to receive shots early. By February 21 Collier had received her second

dose of the Pfizer vaccine. But when the Centers for Disease Control and Prevention gave the green light for vaccinated people to resume prepandemic activities such as gathering indoors without masks on March 8, she did not experience the sense of freedom she had imagined. If anything, she became more fearful of infection. She has yet to eat in a restaurant or see anyone beyond her pandemic bubble. Formerly an avid traveler, Collier says she cannot imagine getting on an airplane again in the foreseeable future.

After a year in isolation, many people who have developed an intimate understanding of what it means to socially isolate are afraid to return to their former lives despite being fully vaccinated. There is even a name for their experience: the clinical sounding “cave syndrome.”

Emerging into the light after a year locked inside is proving to be a difficult transition for some people. Jacqueline Gollan, a professor of psychiatry and behavioral sciences at Northwestern University, says adjusting to the new normal, whatever it may be, is going to take time. “The pandemic-related changes created a lot of fear and anxiety because of the risk of illness and death, along with the repercussions in many areas of life,” she says. “Even though a person may be vaccinated, they still

may find it difficult to let go of that fear because they're overestimating the risk and probability.”

A recent study by the American Psychological Association reported that 49 percent of surveyed adults anticipated being uncomfortable about returning to in-person interactions when the pandemic ends. It found that 48 percent of those who have received a COVID vaccine said they felt the same way.

These long-term psychological effects were not unforeseen. In May 2020 researchers at the University of British Columbia published a study in the journal *Anxiety* that predicted that an estimated 10 percent of people in the midst of the pandemic will develop COVID stress syndrome after coping with severe psychological prob-

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**Melba Newsome** is an independent journalist who has published hundreds of articles in publications that include *Prevention*, *Time*, *Bloomberg Businessweek*, *Wired*, *Glamour*, *Playboy*, *Oprah*, *Reader's Digest*, *Parade* and the *New York Times*.

lems, such as post-traumatic stress disorder (PTSD) or mood or anxiety disorders.

Alan Teo, an associate professor of psychiatry at Oregon Health and Science University, attributes cave syndrome to three factors: habit, risk perception and social connections. “We had to learn the habit of wearing masks, physical distancing or social distancing, not inviting people over,” he says. “It is very hard to break a habit once you form it. There is this disconnect between the actual amount of risk and what people perceive as their risk.” He adds that there is a focus on “the risk of infection and death rather than the risk of dying from being lonely and disconnected.”

People are reluctant to resume their pre-COVID lives for different reasons. Some still have an extreme fear of the disease while others do not want to forfeit what they found to be the positive benefits they derived from the forced isolation and solitude.

University of California, Los Angeles, undergraduate student Genesis Gutierrez discovered he has actually preferred his pandemic lifestyle, especially the money he has saved by attending college virtually. “Postpandemic life means I would have to move to L.A. again and pay for a ridiculously expensive apartment to go to classes that I’ve been able to go to in my home,” he says. “I’ve been able to work from home, do stuff outside of academics and learn more about myself.”

Advances in technology, Teo says, have put people at more risk of developing hikikomori, an extreme version

of social withdrawal lasting six months or longer that superficially resembles effects of agoraphobia, the fear of open or crowded places. “The \$10,000 question is whether the prevalence of this type of extreme condition may be increasing as a result of COVID,” Teo says, “particularly in young people or adolescents, where the risk is greater because that stage is often when this extreme social withdrawal has been identified.”

So what can be done if someone is afraid to go out? Do people suffering from cave syndrome need professional treatment or just a bit more adjustment time? Northwestern’s Gollan says it all depends on the level of severity. If a person has symptoms of exhaustion, depression or anxiety, she advises measures that provide a sense of purpose in life: meditation, faith work, prayer, playing or listening to music.

Treatment for more extreme levels of anxiety require effective psychotherapy with a mental health professional who can offer cognitive therapy or other treatments that gradually expose a person to a stressful situation to resolve their fears. Medication may also be used at times.

Teo says there is a type of distorted thinking that maybe things will be better later. “Based on what we understand about immunity and the variants coming onboard, quite the opposite is true,” he adds. **M**

*Read more about the coronavirus outbreak from Scientific American [here](#). And read coverage from our international network of magazines [here](#).*

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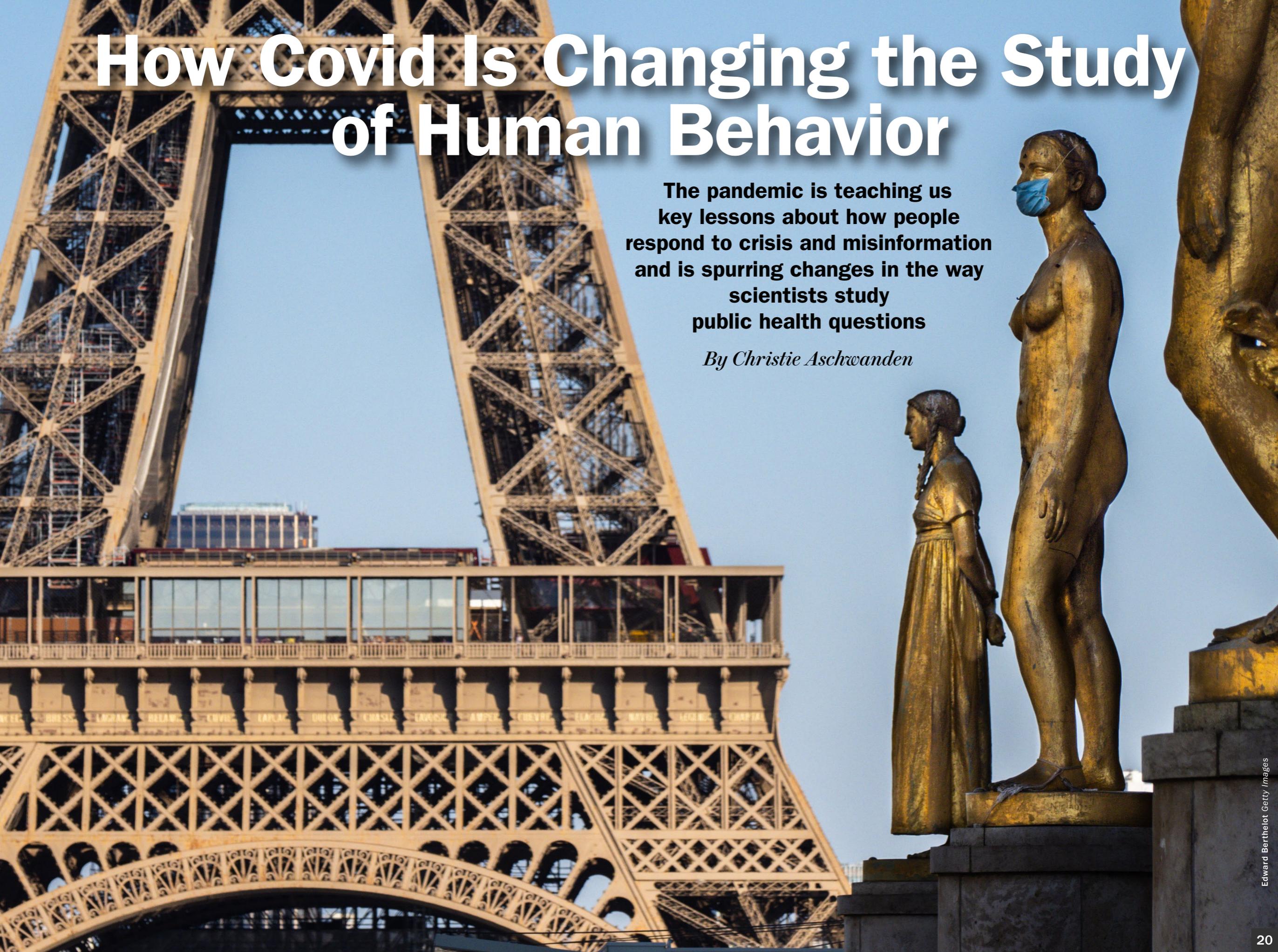
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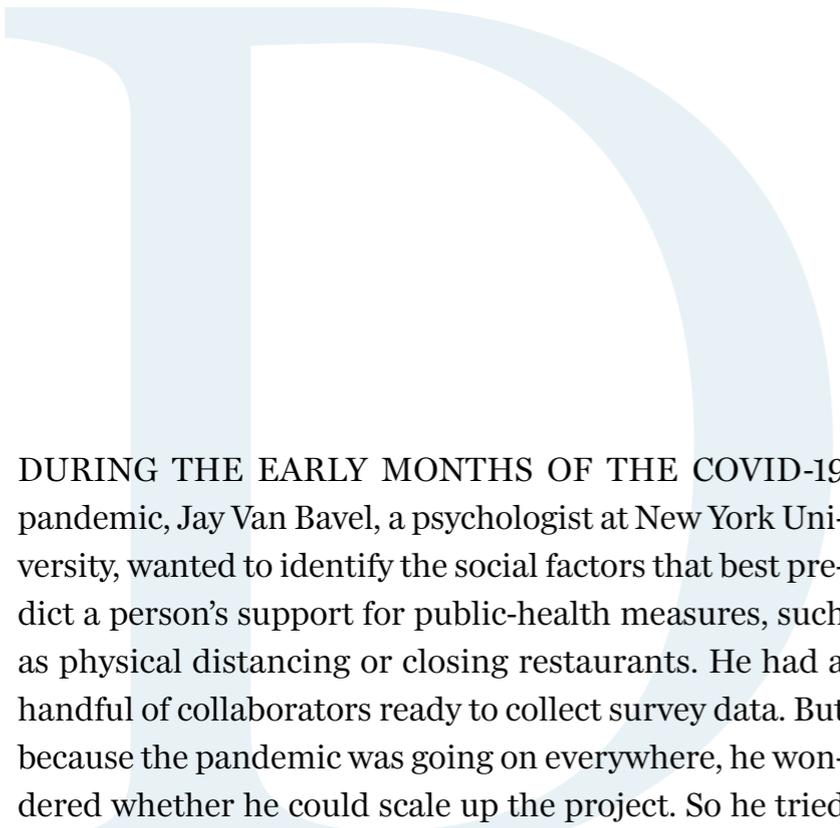


# How Covid Is Changing the Study of Human Behavior

**The pandemic is teaching us key lessons about how people respond to crisis and misinformation and is spurring changes in the way scientists study public health questions**

*By Christie Aschwanden*





DURING THE EARLY MONTHS OF THE COVID-19 pandemic, Jay Van Bavel, a psychologist at New York University, wanted to identify the social factors that best predict a person's support for public-health measures, such as physical distancing or closing restaurants. He had a handful of collaborators ready to collect survey data. But because the pandemic was going on everywhere, he wondered whether he could scale up the project. So he tried something he'd never done before.

He posted a [description of the study on Twitter](#) in April, with an invitation for other researchers to join. “Maybe I’ll get 10 more people and some more data points,” he recalls thinking at the time. Instead, the response floored him. More than 200 scientists from 67 countries joined the effort. In the end, the researchers were able to collect data on more than 46,000 people. “It was a massive collaboration,” he says. The team showed how, on the whole, people who reported that national identity was important to them were more likely to support public-health policies. The work is currently being peer reviewed.

For social scientists, the COVID-19 pandemic has presented a unique opportunity—a natural experiment that “cuts across all cultures and socio-economic groups,” says Andreas Olsson, a psychologist at the Karolinska Institute in Stockholm. Everyone is facing similar threats to their health and livelihoods, “so we can see how people respond differently to this depending on culture, social groups and individual differences,” he says. Researchers have been able to compare people’s behaviors before and after large policy changes, for example, or to study the

flow of information and misinformation more easily.

The pandemic’s global scope has brought groups together from around the world as never before. And with so much simultaneous interest, researchers can test ideas and interventions more rapidly than before. It has also forced many social scientists to adapt their methods during a time when in-person interviews and experiments have been next to impossible. Some expect that innovations spurred by the pandemic could outlive the current crisis and might even permanently change the field.

For example, with the technology that’s now tried and tested, Van Bavel says, it’s much easier to build an international team. “Now that we’ve got the infrastructure and experience, we’ll be able to do this for all kinds of things,” he says.

### SOCIAL VACCINE BOOSTERS

Before Van Bavel’s massive collaboration, he and a group of more than 40 researchers got together to outline the ways in which behavioral research might inform and improve the response to the SARS-CoV-2 coronavirus at a time when people are scared, sceptical and inundated by information. They outlined previous research in the field that might influence policy, and identified potential projects on threat perception, decision-making and science communication, among other things.

Many were eager to apply their work toward understanding the public response to practices such as lockdowns and mask mandates. In the survey of more than 46,000 people, Van Bavel and his colleagues showed that

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countries in which people were most in favor of precautionary measures tended to be those that fostered a sense of public unity and cohesion. A sense, he says, that “we’re all in this together.” That was somewhat counter-intuitive. Right-wing political ideology correlated with resistance to public-health measures among survey participants, but, on the whole, a strong national identity predicted more support for such measures. Van Bavel says this suggests that it might be possible to leverage national identity when promoting public-health policies.

Other work has shown that who delivers the message really matters. A study published in February surveyed more than 12,000 people in six countries—Brazil, Italy, South Korea, Spain, Switzerland and the United States—about their willingness to share a message encouraging social distancing. The message could be endorsed by actor Tom Hanks, celebrity Kim Kardashian, a prominent government official from the survey-taker’s country or [Anthony Fauci](#), director of the U.S. National Institute of Allergy and Infectious Diseases in Bethesda, Md. Respondents from all countries were most willing to share the message when it came from Fauci (although in the United States, where COVID-19 has been highly politicized, he has become a divisive figure for some). Celebrity endorsements were relatively ineffective by comparison.

Preliminary research suggests that aligning the message with recipients’ values or highlighting social approval can also be influential. Michele Gelfand, a psychologist at the University of Maryland in College Park, is part of a team running an “intervention tournament”

to identify ways of promoting mask wearing among conservatives and liberals in the United States.

The researchers are testing eight interventions, or nudges, that reflect different moral values and factors specific to COVID-19. The aim is to work out which are most effective at encouraging these political groups to adhere to public-health guidance. One message they are testing emphasizes that mask wearing will “help us to reopen our economy more quickly”—an approach designed to appeal to Republicans, who are more likely to view the pandemic as an economic crisis than a health one. Another intervention highlights harm avoidance—a value that liberal people say is important to them. The message emphasizes that a mask “will keep you safe.”

“We’re pitting them against one another to see which nudge works best,” Gelfand says. It’s a study design that can test multiple interventions simultaneously, and could be deployed on a large scale across many geographical regions—a benefit made more urgent by the pandemic. The results have not yet been published.

Others started using a similar approach to encourage vaccination even before a SARS-CoV-2 vaccine was available. The Behavior Change For Good Initiative at the University of Pennsylvania in Philadelphia was testing nudges that encourage people to get the influenza vaccine. Katherine Milkman, a behavioral researcher at the university’s Wharton School, and her colleagues tested around 20 messaging strategies—everything from jokes to direct appeals. “We’re seeing things that work,” Milkman says. They’ve found, for example, that texting people to say a flu shot had been reserved especially for them boosted vaccination rates.

The findings were almost immediately put to work by researchers seeking to increase COVID-19 vaccination uptake. Researchers at the University of California, Los Angeles (UCLA), tried replicating the strategy among people being treated at the UCLA Health system in Feb-



A London billboard encouraged people to follow lockdown guidance to prevent COVID-19.

ruary and March, and found that it “proved quite useful for nudging COVID-19 vaccination,” Milkman says.

And, in March, Milkman received an e-mail from Steve Martin, chief executive of the behavioral-science consultancy Influence at Work in Harpenden, U.K., telling her that his team had implemented her findings on the island of Jersey in the English Channel. Martin and his colleague Rebecca Sherrington, associate chief nurse for the Government of Jersey, incorporated Milkman’s insight that it was possible to increase the likelihood of someone coming in for a vaccine if they were given “a sense of ownership”—for instance, by telling them that “this vaccine has been reserved for you.” “We’ve had a real problem engaging care-home staff—particularly young females, many of whom are sceptical about the vaccine,” Martin says. But using Milkman’s approach, along with other insights (such as the idea that the messenger’s identity also matters), Martin’s program attained 93 percent coverage of care-home staff on Jersey, compared with around 80 percent in other jurisdictions.

### DEPOLARIZATION RESEARCH

Technologies such as geotracking are helping social scientists to trace the way people really behave, not just how they say they do. The response to the COVID-19 pandemic has shown a dramatic split along political lines in many places, and because so many people own smartphones that include GPS trackers, researchers can quantify how partisanship has translated into behavior during the pandemic.

Van Bavel and his colleagues used geotracking data from 15 million smartphones per day to look at correlations between U.S. voting patterns and adherence to public-health recommendations. People in counties that voted for Republican Donald Trump in the 2016 presidential election, for example, practiced 14 percent less physical distancing between March and May 2020 than

did people in areas that voted for Democrat Hillary Clinton. The study also identified a correlation between the consumption of conservative news and reduced physical distancing, and found that the partisan differences regarding physical distancing increased over time.

The research possibilities opened up by geotracking are “beyond my dreams,” says Walter Quattrociocchi, a data scientist at the Ca’Foscari University of Venice, Italy. “We have so much more data to measure social processes now,” he says, and the pandemic has provided a way to put these data to work.

His group used location data from 13 million Facebook users to look at how people moved around France, Italy and the United Kingdom during the early months of the pandemic. The three countries displayed different patterns of mobility that reflect their underlying infrastructure and geography. Movements in the United Kingdom and France were more centralized around London and Paris, respectively, but were more dispersed among Italy’s major population centers. Such results, he says, could help to predict economic resilience in the face of other disasters.

Researchers are also increasingly using Internet-based surveys, a trend accelerated by the pandemic. A U.S. study of people’s daily activities during the pandemic—such as going to work, visiting family or dining at restaurants—received more than 6,700 responses per day on average. Results showed that political partisanship had a much greater role than did local COVID-19 rates in influencing safe behaviours. Self-identified Republicans were nearly 28 percent more likely to be mobile than Democrats were, and this gap widened over the course of the study period from April to September last year.

### POST-LOCKDOWN LEGACY

The pandemic is clearly changing how researchers study behavior—and in ways that could outlast the lockdowns.

“I think people will continue to seek to do bigger studies with more laboratories to produce more robust and widely applicable findings,” says Van Bavel. The samples collected through these projects are more diverse than they are for typical approaches, and so the impact from these studies could be much higher, he says.

The COVID-19 crisis has also made researchers much more willing to collaborate and share information, says Milkman. And the pace of publishing and implementing findings has sped up, she says. “I wrote a paper about some of our findings over the Christmas holidays in a week,” she says—work that would have normally taken her several months. She expedited the manuscript because she felt the findings were urgent and she wanted to get them into the public domain.

The constraints of COVID-19 have nudged social science in a good direction, says Milkman. “We should be doing ‘big science,’” she says, in the way that fields such as physics and astronomy do. Instead of running single, small experiments, researchers can now conduct megastudies that bring together large groups of researchers to test 20 or even 50 treatment arms at once, she says.

The inability to gather people indoors to conduct research has also forced innovations in how scientists recruit and study participants, says Wändi Bruine de Bruin, a behavioral scientist at the University of Southern California in Los Angeles. She is an investigator on the Understanding America Study, which has been repeatedly surveying about 9,000 nationally representative U.S. households on questions related to the pandemic, such as “Do you intend to get vaccinated?” and “How likely do you think it is that you will become infected?” Being forced to develop procedures to recruit large, nationally representative samples has allowed Bruine de Bruin and her colleagues to recruit more widely. “You don’t have to stay local,” she says, and because participants don’t have to come into the lab, it’s easier to recruit

a more diverse sample. “I do think it will push social science forward,” she says.

Technical workarounds spurred by the pandemic could also end up strengthening science. Alexander Holcombe, a psychologist at the University of Sydney, Australia, studies visual perception, which he describes as “a very narrow area of science where people weren’t doing online studies” before the pandemic. Social-distancing practices forced him and his team to learn the computer programming necessary to make their experiments work online. The upshot is that they’re able to get bigger sample sizes, he says—an important improvement on the methodology.

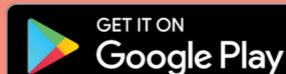
Brian Nosek, executive director at the Center for Open Science, a non-profit organization in Charlottesville, Va., sees the pandemic as a chance to rethink some of the fundamentals of how science is done. “It’s given us an occasion to say, ‘Well, how should we be doing this?’” he says, with “this” being everything from teaching and lab work, to study designs and collaboration. The ways that people communicate in the field and engage with collaborators have “fundamentally changed,” he says. “I don’t imagine we’ll go back.” **M**

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# COVID Has Put the World at Risk of Prolonged Grief Disorder

**COVID** deaths are leaving millions bereaved. For some, the intense grief never recedes, making daily life almost impossible

*By Katherine Harmon Courage*

## THE DEATHS OF NEARLY 600,000 PEOPLE IN THE U.S.

from COVID since the spring of 2020 have left many millions grieving. A sizable number of these bereaved individuals will find their anguish lasts an unusually long time, does not diminish and renders their life almost unbearable, mental health specialists say.

People who sufferer this intense bereavement are frequently unable to keep their job, leave their home or care for other loved ones. Even those who are able to navigate some of everyday life describe their agonized existence as just waiting to die. Their continued high level of stress can damage the body, increasing inflammation and risks for associated illnesses such as heart disease.

This condition, a psychiatric state called prolonged grief disorder, typically lasts for many months after a loss—one year in the U.S. or six months per international criteria. The condition is much worse than normal grieving, says Katherine Shear, a psychiatrist at the Columbia University School of Social Work and founder of the Center for Complicated Grief. And the isolation surrounding so many pandemic deaths likely makes people more vulnerable to it. “There are so many aspects of the pandemic that are going to be risk factors for people having a hard time adapting to these losses,” Shear says.

The number of people with prolonged grief in the near future and beyond could be substantial. A July 2020 study published in the *Proceedings of the National Academy of Sciences USA* estimated that each U.S. COVID death leaves, on average, approximately nine close relatives bereaved. If 5 to 10 percent of the bereaved group develops this disorder—which is the standard rate under normal circumstances—this could put the prevalence of prolonged grief

at an additional quarter of a million to half a million cases in the coming year. Other data hint the toll could be much higher. A March 2021 poll from the Associated Press–NORC (AP-NORC) Center for Public Affairs Research found that about 20 percent of people surveyed in the U.S. had lost a relative or close friend to COVID. That means a potential bereaved population of about 65 million, and it could push numbers of new prolonged grief cases into the millions.

Because COVID deaths have disproportionately occurred among low-income communities and people of color, prolonged grief will likely have an outsized effect on those populations, Shear and other therapists say. What is especially worrisome is that these communities, and the U.S. in general, do not have sufficient mental health resources—therapists and facilities—to address a problem of this magnitude. “If we don’t find ways to bring attention to the emotional suffering that people are coping with right now, it will turn into more serious problems,” says Vickie Mays, a professor of health policy and management at the University of California, Los Angeles, Fielding School of Public Health.

### A WOUND THAT TIME WILL NOT HEAL

Grief can be terrible. Most people, however, eventually integrate their loss and find a way forward, even as they

continue to mourn their loved ones. Mary-Frances O’Connor, a clinical psychologist at the University of Arizona specializing in grief and its physiological impacts, likens this process to healing a broken leg: For the majority of people, rest and a cast will allow it to return to normal. Yet for a subset, a complication will arise—an infection or secondary trauma to the area—that prevents it from healing properly without more intensive intervention. In bereavement, those are the people with prolonged grief.

O’Connor describes one patient she worked with who lost her job because she could not get through standard work conversations without breaking down in tears for months on end. Another patient felt it would be meaningless to have religious celebrations for her children after losing her mother. “These types of complications really do impact daily functioning for people,” O’Connor says.

The health implications of the disorder can be serious. It can exacerbate suicidality and substance use. It is also linked to systemic damage to the body. O’Connor found that people experiencing grief have higher levels of inflammation, particularly the cytokine interleukin-6, which has been linked to increased risk of cardiovascular disease and greater susceptibility to infections. O’Connor notes that long-term psychological and social distress leads to a harmful “weathering” in the body, a well-established state of prolonged biological stress that predisposes people to greater disease risk and earlier health decline.

There are already signs that the pandemic is creating higher levels of serious grieving disorders, says psychologist Robert Neimeyer, director of the Portland Institute

for Loss and Transition in Oregon and an author of several books on grief therapy. He sees “worrisome signals” that there will be a higher incidence of prolonged grief. Research published earlier this year in the journal *Globalization and Health* found signs of prolonged grief in nearly 38 percent of pandemic-bereaved individuals from China. That number is more than triple the typical rate, Neimeyer notes.

Researchers say there are many aspects of the pandemic that are likely to increase the risk of the disorder. One cause may be the circumstances surrounding most COVID deaths. “There’s a lot of trauma associated with [a coronavirus] loss,” Shear says. Whether these deaths occur in a hospital or at home, people are struggling to breathe, and the patient is usually isolated because of infection concerns. “It’s happening kind of randomly and quickly and dramatically, and people are suffering a great deal,” she adds. “They’re not peaceful deaths by any means. And they’re also occurring alone.”

The lack of contact with a loved one before or during death can add to the likelihood the bereaved will ruminate on alternative outcomes, preventing them from accepting the reality of the loss. O’Connor says that relatives often wonder, “What if I had done this? What if the doctor had done that?” There are an infinite number of things that could have happened, and that rumination process seems to get in the way of returning to a meaningful life. Previous research has found that meaningful communication with a loved one before their death reduces the risk of survivors developing persistent issues with grief later on. But this often has not been possible in person, or at all, with those who died from COVID.

Another contributing factor for people who lost loved ones during the pandemic—from COVID or another cause—may be the past year of public health measures that limited gatherings, travel and close interpersonal contact. Although these measures have proved essential

for controlling the spread of SARS-CoV-2, and the death and hospitalization numbers would be much higher without them, “grief is complicated by taking away so many of the traditional ways you would grieve,” Mays says. A memorial over Zoom is “a far cry from being able to really come together with others and experience the consolation of a human hug,” Neimeyer says. The restrictions also reduced people’s ability to create new experiences and social connections after a loss, a key step in acclimating, Shear notes. The pandemic has increased the incidence of mood and anxiety disorders and substance use, all of which put people at greater risk for prolonged grief disorder.

Other pandemic stresses—from financial problems to health and safety concerns—can make adapting to a loss more difficult because they distract people from processing it, Shear notes. This is likely affecting a disproportionate percentage of people in communities hit hardest by the pandemic. Some have lost more than one loved one, some have lost a job and/or home, and many have been burdened with significant financial strains resulting in food or housing insecurity. “When you have a lot of uncertainty, that makes it more difficult to go through a grieving process,” Mays says.

### TREATMENT COSTS

There are effective, science-backed treatments for prolonged grief, but they involve months of therapy. Professionals in Europe, for example, treat the disorder with more than two months of group and individual therapy sessions to address patients’ behavior and responses. Shear’s group at Columbia has developed a 16-week one-on-one treatment protocol, validated through research, that focuses on adapting to loss.

Offering such intensive interventions in historically marginalized communities, with fewer financial and health resources and yet more risk, is challenging, Shear

notes. In a small study, her team found its treatment program was equally effective among white and Black Americans. But the number of people of color who may be suffering from prolonged grief will likely be high because of the disproportionate impact of COVID on their communities. The AP-NORC poll about losses found that while about 15 percent of white respondents had lost someone close to them to COVID, that percentage doubled for Black and Latinx individuals.

Access to mental health care in the U.S. is lacking, with approximately 30 psychologists and fewer than 16 psychiatrists per 100,000 people. That ratio is even more lopsided in communities that have suffered the most during the pandemic. “It looks even more abysmal,” Shear says, and it’s another aspect of systemic racism in health care in the U.S. According to Shear, many therapists are not aware of prolonged grief disorder, because mental health professionals in general receive little to no training in treating even typical grief.

There are less intensive approaches that can provide some help, Mays says. For starters, she advocates for a safe return to rituals, community support, and communal commemoration and conversations around pandemic losses. “I’m not big on believing that we need people to be in one-on-one mental health services,” she says. O’Connor adds that if we can also better alleviate some of the secondary stressors many people are facing—lack of food, for instance—they will be better equipped to recover from loss. “For a person who has sufficient housing and food security and child care, now suddenly you have the bandwidth to understand what it means that you lost your mom,” she says.

As the U.S. works its way out of the immediate viral threat, Neimeyer emphasizes that the need for solutions to this shadow mental health breakdown is growing. “This pandemic of grief is one for which there is no vaccine,” he says. **M**

**Wendy Chung** is principal investigator for SPARK (Simons Foundation Powering Autism Research for Knowledge); Kennedy Family Professor of Pediatrics and Medicine at Columbia University Vagelos College of Physicians and Surgeons; and a clinical and molecular geneticist and physician at New York–Presbyterian/Columbia University Irving Medical Center. In 2020 she was elected to membership in the National Academy of Medicine.

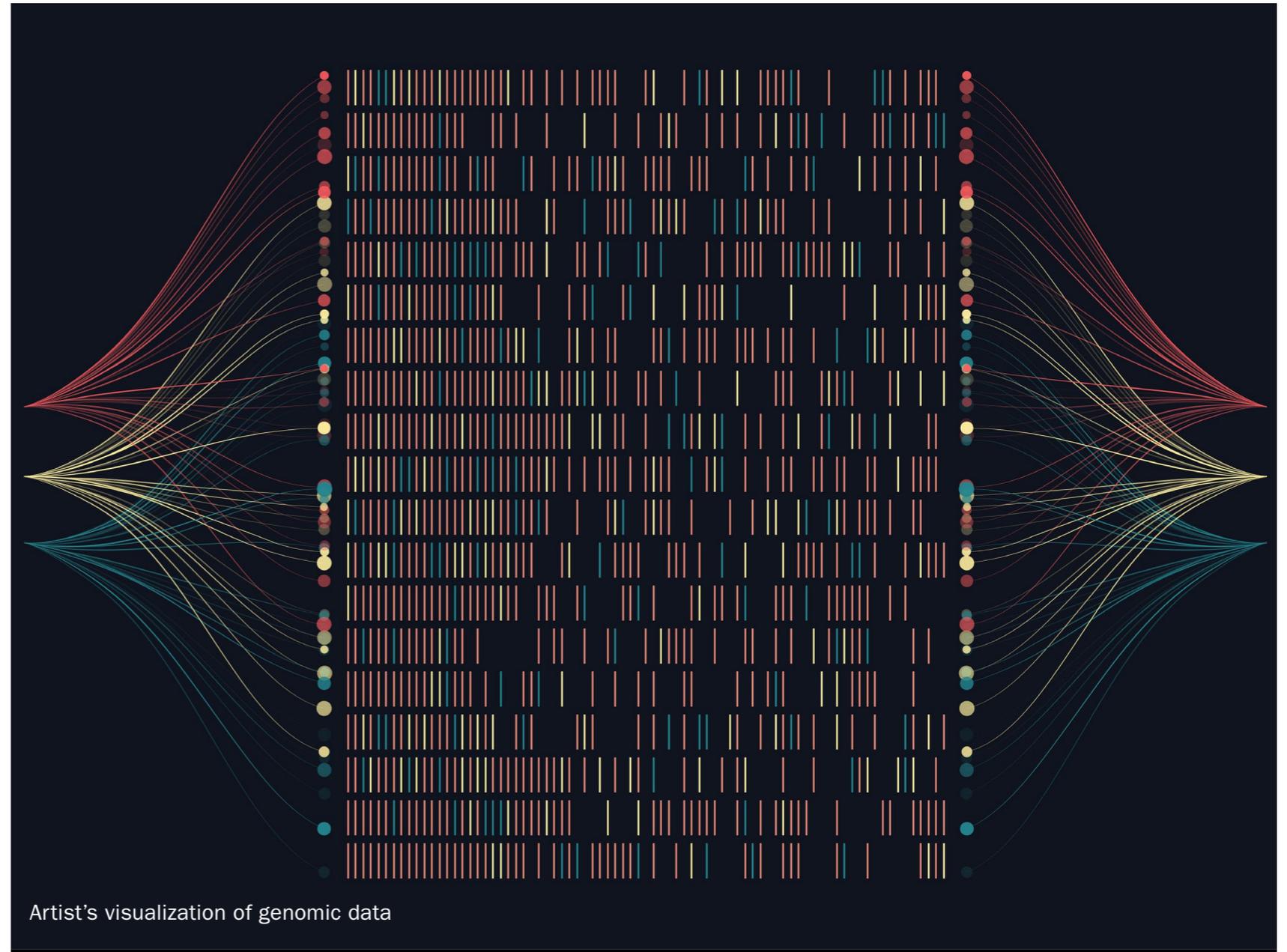
NEUROLOGICAL HEALTH

# How Big Data Are Unlocking the Mysteries of Autism

Better genetic insights can help support people across the spectrum

When I started my pediatric genetic practice more than 20 years ago, I was frustrated by constantly having to tell families and patients that I couldn't answer many of their questions about autism and what the future held for them. What were the causes of their child's particular behavioral and medical challenges? Would their child talk? Have seizures? What I did know was that research was the key to unlocking the mysteries of a remarkably heterogeneous disorder that affects more than five million Americans and has no FDA-approved treatments. Now, thanks in large part to the impact of genetic research, those answers are starting to come into focus.

Five years ago we launched SPARK (Simons Foundation Powering Autism Research for Knowledge) to harness the power of big data by



Artist's visualization of genomic data

engaging hundreds of thousands of individuals with autism and their family members to participate in research. The more people who participate, the deeper and richer these data sets

become, catalyzing research that is expanding our knowledge of both biology and behavior to develop more precise approaches to medical and behavioral issues.

SPARK is the world's largest autism research study to date with over 250,000 participants, more than 100,000 of whom have provided DNA samples through the simple act of spitting in a tube. We have generated genomic data that have been de-identified and made available to qualified researchers. SPARK has itself been able to analyze 19,000 genes to find possible connections to autism; worked with 31 of the nation's leading medical schools and autism research centers; and helped thousands of participating families enroll in nearly 100 additional autism research studies.

Genetic research has taught us that what we commonly call autism is actually a spectrum of hundreds of conditions that vary widely among adults and children. Across this spectrum, individuals share core symptoms and challenges with social interaction, restricted interests and/or repetitive behaviors.

We now know that genes play a central role in the causes of these "autisms," which are the result of genetic changes in combination with other causes, including prenatal factors. To date, research employing data science and machine learning has identified approximately 150 genes related to autism but suggests there may be as many as 500 or more. Finding additional genes and commonalities among individuals who share similar genetic differences is crucial to advancing autism research and developing improved supports and treatments. Essentially we will take a page from the playbook that oncologists use to treat certain types of cancer based on their genetic signatures and apply targeted

therapeutic strategies to help people with autism.

But to get answers faster and be certain of these results, SPARK and our research partners need a huge sample size: "bigger data." To ensure an accurate inventory of all the major genetic contributors and to learn if and how different genetic variants contribute to autistic behaviors, we need not only the largest but also the most diverse group of participants.

The genetic, medical and behavioral data SPARK collects from people with autism and their families is rich in detail and can be leveraged by many different investigators. Access to rich data sets draws talented scientists to the field of autism science to develop new methods of finding patterns in the data, better predicting associated behavioral and medical issues, and, perhaps, identifying more effective supports and treatments.

Genetic research is already providing answers and insights about prognosis. For example, one SPARK family's genetic result is strongly associated with a lack of spoken language but an ability to understand language. Armed with this information, the medical team provided the child with an assistive communication device that decreased tantrums that arose from the child's frustration at being unable to express himself. An adult who was diagnosed at age 11 with a form of autism that used to be known as Asperger's syndrome recently learned that the cause of her autism is KMT2C-related syndrome, a rare genetic disorder caused by changes in the gene *KMT2C*.

Some genetic syndromes associated with autism also confer cancer risks, so receiving these re-

sults is particularly important. We have returned genetic results to families with mutations in *PTEN*, which is associated with a higher risk of breast, thyroid, kidney and uterine cancer. A genetic diagnosis means that they can now be screened earlier and more frequently for specific cancers.

In other cases, SPARK has identified genetic causes of autism that can be treated. Through whole exome sequencing, SPARK identified a case of phenylketonuria (PKU) that was missed during newborn screening. This inherited disorder causes a buildup of amino acid in the blood, which can cause behavior and movement problems, seizures and developmental disabilities. With this knowledge, the family started their child on treatment with a specialized diet that included low levels of phenylalanine.

Today, thanks to a growing community of families affected by autism who, literally, give a part of themselves to help understand the vast complexities of autism, I can tell about 10 percent of parents what genetic change caused their child's autism.

We know that big data, with each person representing their unique profile of someone impacted by autism, will lead to many of the answers we seek. Better genetic insights, gleaned through complex analysis of rich data, will help provide the means to support individuals—children and adults across the spectrum—through early intervention, assistive communication, tailored education and, someday, genetically based treatments. We strive to enable every person with autism to be the best possible version of themselves.

**Andy Norman** directs the Humanism Initiative at Carnegie Mellon University. He studies how ideologies short-circuit minds and develops antidotes to mental immune disruptors. His book *Mental Immunity* is forthcoming in 2021.

BEHAVIOR & SOCIETY

# The Cause of America's Post-Truth Predicament

**People have been manipulated to think that beliefs needn't change in response to evidence, making us more susceptible to conspiracy theories, science denial and extremism**

In the hours after our new president was sworn in on January 20, an online discussion channel followed by 35,000 QAnon believers was rife with disbelief. "It simply doesn't make sense that we all got played," one poster wrote. But they did get played. So did we all.

Of course, we were played in different ways. QAnon devotees were fed a ludicrous story about Satan-worshipping, "deep state" pedophiles plotting to oust then president Donald Trump. The anonymous source of the story—"Q"—promised a purge, and tens of thousands pinned their hopes on that happening before Joe Biden could take office. Clearly, Q played them.

The insurrectionists of January 6 were also played. At his rally to "stop the steal," Trump fired



Q-Anon sign is seen as President Donald Trump supporters hold a rally on January 5, 2021, in Washington, D.C.

up his audience, then sent them to the Capitol to prevent the certification of his election loss. "We [need to] fight like hell," he said. "We're going to walk down, and I'll be there with you." Only he didn't, and he wasn't. Later, he denounced the very rioters he'd incited and left them to suffer the legal consequences of his sedition. "Trump just used us," said Lenka Perron, a former QAnon

believer. She went on to explain that when you're "living in fear, (you're) prone to believe this stuff." Many Republicans don't seem to recognize that they, too, are being played. The GOP now trades almost exclusively in manufactured bogeymen. "Death panels," "feminazis," and the "war on Christmas" are obvious ploys, but fearmongering is now the defining feature of American conser-

## When we affirm one another’s “right” to believe things—even things that fly in the face of evidence—we essentially decouple critical thinking and belief revision.

vatism. Socialists aim to destroy our way of life. The government is planning to seize your guns. Secularists will steal your freedom to worship. Gays will destroy the institution of marriage. Black Lives Matter protesters will burn down your neighborhood. Cognitive scientists call what Republican strategists do “amygdala hijacking,” after the brain module that responds to fear.

But brains manipulated in this way lose the capacity for reasoned reflection. When Sean Hannity and Tucker Carlson feed you grievance after grievance—Benghazi! Hillary’s e-mails! Election theft! —they’re suppressing your higher brain function. They’re playing you.

But let’s be honest: we liberals are also being played. When we fixate on the wingnut outrage of the day and nurse our own grievances, we suppress our own higher brain function. (The human brain can actually become addicted to grievance.) Right-wing provocateurs love to “own the libs,” and too often we liberals play along. When we do, we play ourselves.

You don’t have to be a conspiracy theorist to see deeper forces at work here. America’s founders universally acclaimed the so-called liberty of conscience. But over time this admirable principle morphed into the idea that everyone has a right to believe as they please. And so even liberal stalwarts such as Daniel Patrick Moynihan avow that we’re “entitled” to our opinions. The trouble with this idea is that it interferes with efforts to promote accountable talk: call something a “right,” and anything that impinges on it counts as transgressive—transgressive, in fact,

of something sacred. (Rights belong to a category of things psychologists call “sacred values”—things we’re not supposed to trade off against other things.)

But evidence and critical questioning can (and should) impinge on belief, and that makes them transgressive of something we are conditioned to see as a right. In this way, we have made critical thinking about core values all but taboo. A core American value systematically subverts critical thinking.

When we affirm one another’s “right” to believe things—even things that fly in the face of evidence—we essentially decouple critical thinking and belief revision. This damages the norm that keeps minds tethered to reality. A Canadian research team recently made an important discovery: when people lose the “meta-belief” that beliefs should change in response to evidence, they become more susceptible to conspiracy theories, paranormal beliefs, science denial and extremism—mind viruses, if you will.

This is a critical finding. I like to put it more simply: the idea that beliefs should yield to evidence is the linchpin of the mind’s immune system: remove it—or even chip away at it—and an Inter-

net-connected mind will eventually be overrun by mind parasites. When this happens to enough minds, all hell breaks loose.

This is the root cause of our post-truth predicament. When we buy into the prevailing fundamentalism about speech rights or downplay the importance of accountable talk, we exacerbate an increasingly existential problem.

The deep culprit here is not a shadowy government insider. It’s not an aspiring demagogue or a corrupt political party. Trace the problem to its roots, and you find a compromised cultural immune system. Astonishingly irrational ideas proliferate because they’re playing us.

If we continue to let them play us, we’ll chase one another down the rabbit hole of delusion. There’s really only one alternative. First, we must grasp that bad ideas are mind parasites—entities that can proliferate and harm the very minds that host them. In fact, they can lay waste to delusion-tolerant cultures. Second, it’s time to take the emerging science of mental immunity seriously. We must grasp how mental immune systems work and work out how to strengthen them. Then, we need to inoculate one another against the worst forms of cognitive contagion.

MENTAL HEALTH

# Major Depressive Disorders Have an Enormous Economic Impact

Their prevalence has more than tripled during the pandemic, but the trends were already troubling long before it arrived

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Since the early 1990s I, together with my colleagues, have been studying the economic burden of adults with major depressive disorders (MDD). Over that time we have tracked shifts in the prevalence of this disease; in the makeup of those suffering from it; and in the nature of treatment both for the disease itself and for the host of comorbidities, such as pain and anxiety disorders, that accompany it. We have then used these data as the basis for calculating the incremental economic burden of adults with MDD—that is, the additional costs traceable to those suffering from the disease in terms of both medical treatment and workplace productivity impacts.

Our most recent study was published in a spe-



cial issue of *PharmacoEconomics* (which I also co-edited) that presents new research on the economics of MDD. By focusing on one year during the Great Recession (2010) and another

after a long macroeconomic expansion (2018), our analysis provides a helpful profile of the changing economic effects of this widespread and pernicious illness. We report our latest esti-

mates showing that the incremental economic burden of adults with MDD was \$326 billion in 2018, 38 percent higher than in 2010.

But our work goes deeper than simply providing an economic calculator. This research offers a multifaceted lens through which we can gain a better understanding of how the myriad effects of the illness manifest themselves.

More important, we find that only 11 percent of the overall burden of illness was attributable to the direct medical costs of treating MDD itself, whereas the costs of treating comorbid medical conditions made up 24 percent. Another 4 percent was the result of suicide-related costs, and fully 61 percent of the total burden in 2018 resulted from a combination of elevated workplace absenteeism and presenteeism (that is, reduced productivity as a result of working while sick). This striking imbalance between medical expenditures to treat either MDD or its comorbidities on the one hand and workplace-related costs on the other is one aspect of the story that has changed dramatically since 2010, when medical costs were equivalent to workplace costs.

Several other things have also changed meaningfully in the interim. First, the COVID-19 pandemic has so visibly altered our world since early 2020. Although the full effects of the pandemic on MDD will not be fully understood for some time, the Centers for Disease Control and Prevention estimates the average prevalence to be 27 percent during the pandemic, more than three times its 2019 rate of 71 percent. Of course, it is not yet clear the extent to which this much higher

prevalence rate will endure postpandemic. But the unprecedented rise in the number of MDD sufferers seems likely to translate into a higher burden of illness, even though its precise magnitude and composition will not be known for some time.

A second significant change that we document in our latest study is that the prevalence of illness now includes many more younger people than ever before. Of the 15.5 million MDD sufferers in 2010, 5.4 million (35 percent) were between 18 and 34 years of age. In contrast, there were 17.5 million people who suffered from MDD in 2018, 8.3 million (47 percent) of whom were in this younger age cohort. This shift to a younger age mix likely results in added burdens at work, home and school. Since the age of onset usually occurs by the time an MDD sufferer is a young adult, without effective and timely intervention, these individuals are especially vulnerable to potentially irreversible adverse life outcomes, including drop-out from high school or college, teenage parenting, and marital or job instability.

A third key trend relates to the deceleration in the MDD treatment rate that we have seen over time. Although it doubled from 28 percent in 1990 to 56 percent in 2018, the treatment rate has hovered near its current level for the past 15 years. With 44 percent of MDD sufferers not reached at all by the health-care sector, there still exists a substantial unmet treatment need. If broader outreach and more effective forms of care can help shift more of the direct medical expenditures to treatment of MDD itself rather

than treatment of comorbid physical and psychiatric conditions, such a change would be wholly welcome.

A fourth important trend we observe focuses on more favorable employment conditions in 2018 compared with 2010. Throughout the business cycle, labor-force attachment tends to be far more volatile for people with MDD. Although they are highly employable, especially in economically robust times, MDD sufferers are often disproportionately adversely affected during economic declines (particularly those aged 50-plus).

One recurring insight from our body of research is that there is a complex interaction among MDD prevalence, severity, treatment and employment rates through the business cycle. As a result of this dynamic, there is an inherent tension between societal interests and individual employer interests in terms of who bears the costs of optimal MDD-patient management. This represents a continual challenge even during the best of macroeconomic conditions.

In general, the economic burden of an illness is related to how widespread it is in society, how debilitating it is in terms of resulting impairment among sufferers, and how widely treated it is in the medical sector. Our updated research findings continue to add to our understanding of the burden of illness. But with the effects of the pandemic on MDD still not yet clear, it will take several years to amass relevant data that can shine a bright light on many of these complicated dynamics.

**Stephen Macknik** and **Susana Martinez-Conde** are professors of ophthalmology at the State University of New York and the organizers of the Best Illusion of the Year Contest. They have co-authored *Sleights of Mind: What the Neuroscience of Magic Reveals about Our Everyday Deceptions* and *Champions of Illusion: The Science behind Mind-Boggling Images and Mystifying Brain Puzzles*.

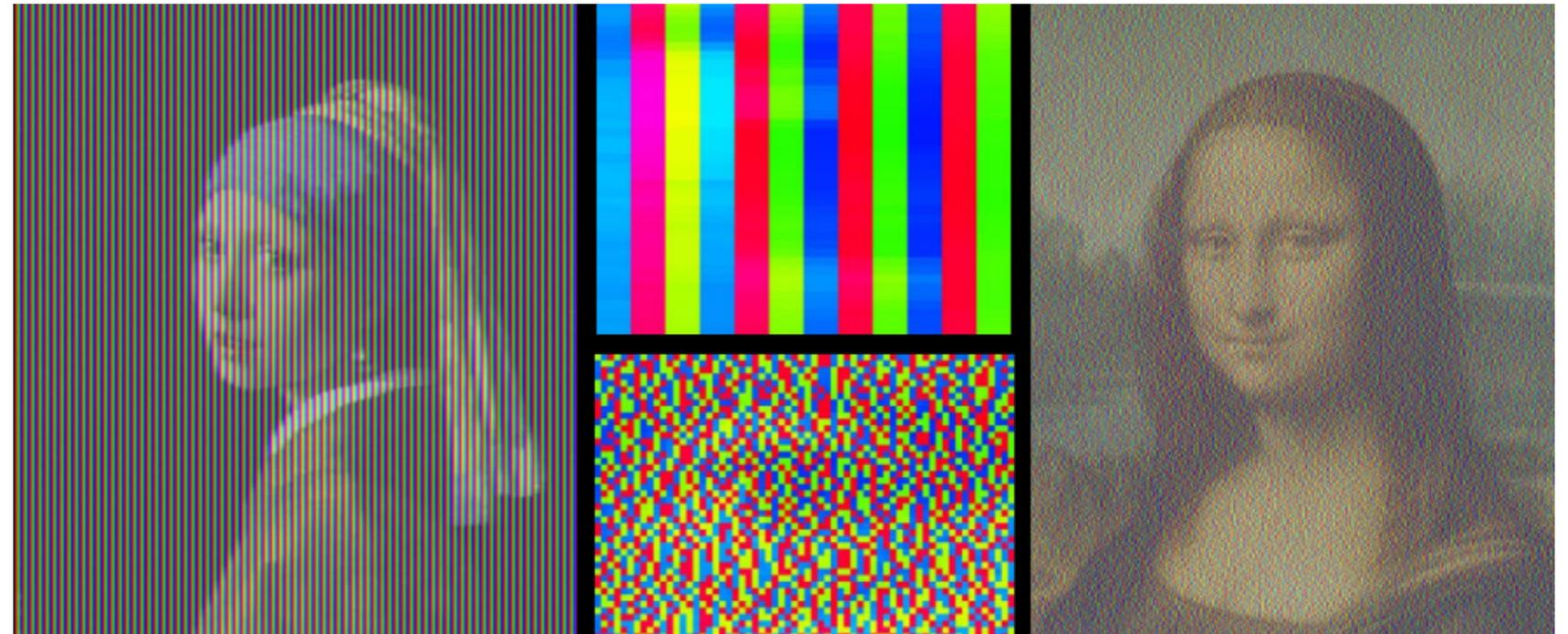
## It's All in the Mix

A new form of color blending produces surprising palettes

Akiyoshi Kitaoka of the Ritsumeikan University in Japan, inventor of countless brain-crushing misperceptions, straddles the realms of visual science and art perhaps more than any other illusion creator today. His newest discovery combines additive and subtractive chromatic schemes to represent opposite ends of an illumination spectrum, bringing new understanding to how we perceive color and brightness.

Kitaoka's breakthrough arose from his realization that he could use vivid colors to create both the dark and bright extremes of the luminance scale. In other words, that he could display full-blast red, green and blue (RGB) pixels on a screen to generate the perception of not only vibrant hues but also dim, shady ones—such as depicted in the images at the top of this page.

Using an RGB scheme to represent the dark end of a brightness spectrum meant that Kitaoka needed even brighter colors to portray the lighter end of the spectrum. The candidate hues were mixes of other vivid colors, such as cyan (blue + green), magenta (blue + red) and



Akiyoshi Kitaoka's versions of Vermeer's *Girl with a Pearl Earring* (left) and Da Vinci's *Mona Lisa* (right). Vermeer's image is made completely from TV-like rows that are fully illuminated as either red, green or blue, to represent dark colors, mixed with cyan, magenta and yellow, to represent bright colors. The upper middle panel is a close-up of the girl's left eye. Da Vinci's image is made from pixels instead of rows. The bottom middle panel is a close-up of Mona Lisa's left eye.

yellow (green + red)—or CMY for short.

These color schemes—RGB versus CMY—have been used for decades as the most common methods of additive and subtractive color mixing. In additive color mixing, such as on a video screen, RGB pixels mix in different amounts to add up to the desired color and brightness. In subtractive color mixing, such as in printing (for example, color printers, T-shirts), dyes that absorb light mix with one another. Hence, red light absorption from white light results in cyan, green absorption results in

magenta and blue absorption results in yellow.

By featuring additive and subtractive color mixing in the same image, Kitaoka's hybrid color scheme accomplishes both dark and light levels of brightness and color, even though each point in the image is blazing at full power.

This "intermediate color mixture" not only bridges additive and subtractive processes, Kitaoka says, but it also reveals that "human vision can distinguish these types of spatial (or temporal) color mixes and perceive every color and lightness from black to white in each image."

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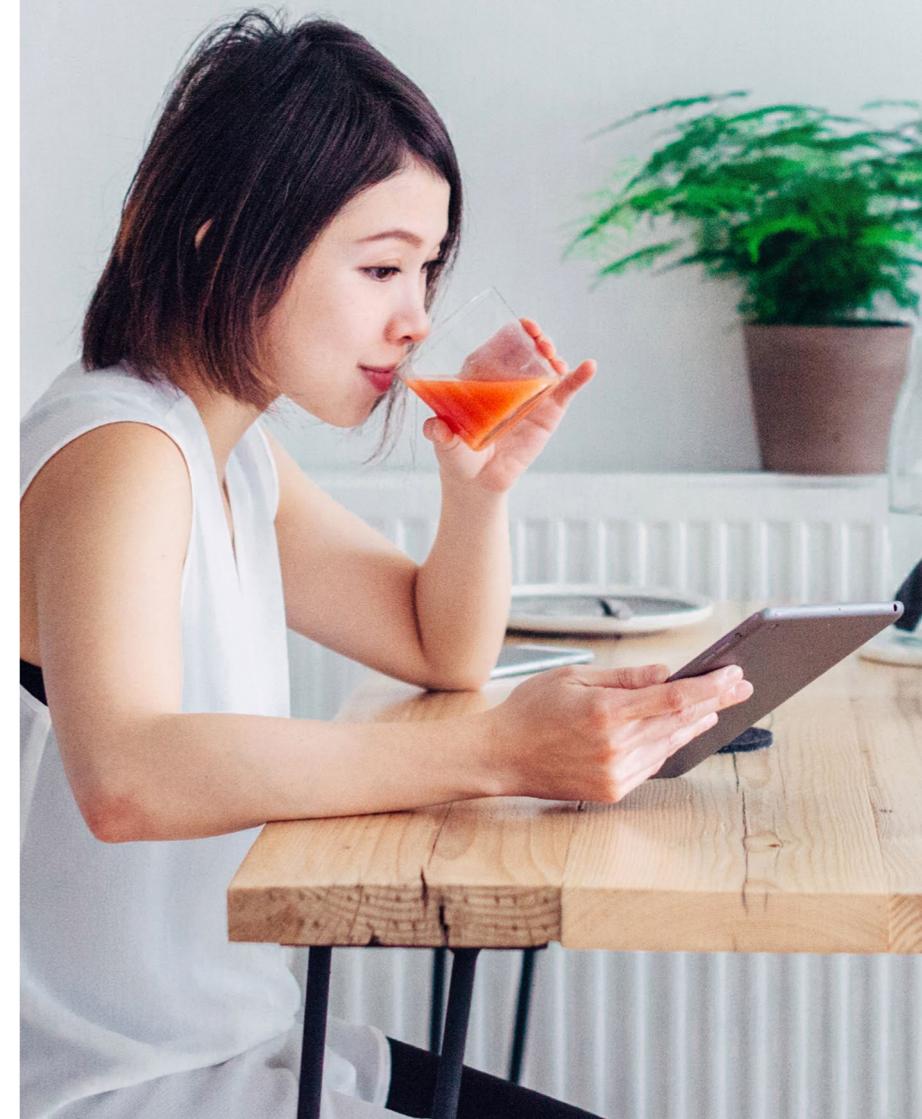
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