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The science of aha! moments

WITH COVERAGE FROM nature

FROM THE EDITOR

Liz Tormes

Carrying On in Difficult Times

I wish I could write that a global pandemic was our only problem at the moment. While the U.S. approaches the sad milestone of one million citizens dead from COVID-19, a devastating land war in Europe is displacing millions, and a rapidly warming planet has caused another Antarctic glacier collapse. Bad news seems to dominate headlines and Twitter feeds. As reporter Francine Russo writes in this issue, the uncertainty of our times has hit some individuals particularly hard (see "The Personality Trait 'Intolerance of Uncertainty' Causes Anguish during COVID").

Even as COVID cases ease in many U.S. states, some people are at risk of withdrawing further into isolation rather than rejoining social events and interactions, as medical experts Carol W. Berman and Xi Chen explain (see "COVID Threatens to Bring a Wave of Hikikomori to America"). But small pleasurable routines can work wonders in an unpredictable world; a mere two hours a week in nature has been shown to improve psychological well-being. As we continue to grapple with whatever news comes our way, we are already doing precisely what is required: we must continue.

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On the Cover

New ways to cope with the unpredictability of life

WHAT'S INSIDE

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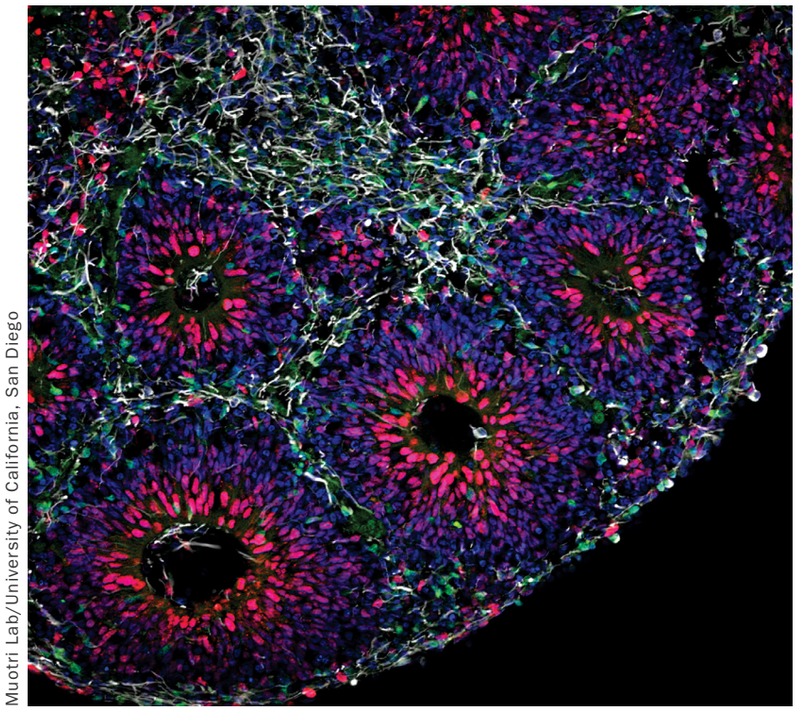

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NEWS

Artificial Neuron Snaps a Venus Flytrap Shut

Researchers say that such biointegrated systems could be the future of prosthetics

When a Venus flytrap snaps its fleshy lobes around an unsuspecting insect, it's game over for the prey. The plant's unusual habit of snacking on animals has captured the imagination of people ranging from Charles Darwin to playwright Howard Ashman and composer Alan Menken (the latter two created the 1982 musical *Little Shop of Horrors*, which stars a human-eating plant). Now, in an experiment that might seem straight out of a pulp science-fiction novel, scientists have harnessed the flytrap's power for themselves: they have developed a method to trigger its trap using

Venus flytrap

baphotte/Getty Images

soft, semiorganic artificial neurons.

"The overarching goal of our research is to try to develop devices that can mimic the functioning of building blocks in our body," says study co-author Simone Fabiano, an organic nanoelectronics researcher at Linköping University in Sweden. The Venus flytrap provides an efficient testing ground for an interface between living creatures and electronics that, Fabiano and his team hope, may one day lead to fully integrated biosensors for monitoring human health—or a better interface for people to control advanced prostheses with their nerves. The results were published in *Nature Communications* in February.

This is not the first time scientists have controlled a Venus flytrap. Alexander Volkov of Oakwood University has been researching plant electrophysiology—and specifically Venus flytraps—for decades. In 2007 he and his lab hooked up silver wires to a flytrap's snapping mechanism and ran an electric current through the system, causing the lobes to clamp shut.

Such experiments work because the motion is controlled by an apparatus similar to an animal's nervous system. In the flytrap, the phloem—the tissue that transports nutrients through a plant—contains ion channels through which charged particles can flow. This triggers the plant's lobes to close, similar to the way electrical charge flows along an animal's nerves to send commands to its muscles. But there are some key differences between the two systems. "In Venus flytraps, calcium mitigates the [electrical] response, whereas in animals, it's usually sodium," says Swetha Murthy, a biochemist at Oregon Health & Science University, who also works with Venus flytraps but was not involved in the new study. Additionally, the plant's membranes are hyperpolarized, compared with animal neurons. This means scientists have to use extra current to induce a reaction in the Venus flytrap. They do so by incorporating charged chloride ions into their electronic device.

Despite these differences, a Venus flytrap's ion channel serves as a good model for testing nerve activity, thanks to the channel's size. "It's easy to measure in experiments," Volkov says. And the trap's big, clamshell-like closing motion is an obvious sign that the signal has gotten through. Plus, there are fewer ethical considerations when it comes to using plants, as opposed to animals, in the lab.

To make their flytrap close, Fabiano and his colleagues constructed a neuronlike electronic device. They began by screen printing carbon and silver chloride electrodes onto a polyester base. "It's what you use for printing labels on T-shirts," Fabiano explains. "It's a very, very simple way of making electronics." Next they attached the electrodes to the lobes and midrib (or crease) of the plant's trap and ran a current through the system—first at a high frequency and then at a lower one. They found the high frequency triggered a quick response, but the low frequency was not enough to close the trap.

This setup was somewhat similar to Volkov's original work and previous research involving artificial neurons but differed in a couple of crucial ways. For one thing, it did not use silicon, a rigid and relatively expensive component of most other artificial neurons. And unlike earlier Venus flytrap studies, it mimicked the structure of an actual neuron by including a tiny gap across which ions can jump (known as a synapse in a real nerve cell) within the screen-printed electrodes.

Although he sees his team's results as encouraging, Fabiano acknowledges that the system is not yet ready to interface with human cells. "We still have a couple of orders of magnitude before we get to the energy efficiency of our biological neurons," he says. Once the artificial neuron becomes more efficient, he thinks this technology could potentially be used to establish a link between a person's signaling nerves and an artificial limb, allowing for seamless prosthetic control.

Volkov is not convinced the new research represents a true breakthrough. Many researchers have designed systems to interface with plants, he says. "Some people have closed Venus flytraps by smartphone," Volkov adds. Given the difference in plant and animal physiology, he is uncertain the system could translate to real neurons controlling an external device.

Murthy is more optimistic. "I think this study provides strong potential to develop and integrate implantable devices as biosensors," she says. "It's a proof-of-principle experiment."

—Joanna Thompson

Aha! Moments Pop Up from Below the Level of Conscious Awareness

People in a study handily solved puzzles while juggling an unrelated mental task by relying on spontaneous insight, not analytic thinking

Iya Forbes/Getty Images

Most of us have had the experience of struggling mightily to solve a problem only to find, while taking a walk or doing the dishes, that the answer comes to us seemingly from nowhere. Psychologists call these sudden aha! moments "insight." They occur not only when we are faced with a problem but also when we suddenly "get" a joke or crossword puzzle clue or are jolted by a personal realization. Scientists have identified distinctive brain activity patterns that signal moments of insight, but there is still some debate about whether insight is simply the final, most satisfying step in a deliberative thought process or a wholly separate form of thinking.

An ingenious new study by a team of Belgian psychologists provides additional evidence that insight engages unconscious mechanisms that differ from analytic, step-by-step reasoning. Even when people are managing multiple demands on their brainpower, the research suggests their intuitive thought processes may still be readily accessible.

"You can be overloaded by all this type of stuff, cell phones or whatever, and your insights remain shielded," says Hans Stuyck, a doctoral student at Université Libre de Bruxelles and KU Leuven in Belgium, who led the study.

For that investigation, which was first published online in December 2021 in the journal *Cognition*, the psychologists created 70 word puzzles that undergraduate students could solve using either insight or analytic reasoning. Each puzzle consisted of three Dutch words displayed on a computer screen. The task was to find a fourth word that pairs with each. (For example, if the test were conducted in English, people might be given the words "artist," "hatch" and "route," with the answer being "escape" because "escape artist," "escape hatch" and "escape route" are all recognizable phrases.)

The 105 undergraduates, most of whom were women, had up to 25 seconds to solve each problem. After typing an answer, they indicated whether they had reached it "with aha!"—which they were told meant

becoming "aware of the solution suddenly and clearly," like a lightbulb illuminating a dark room—or calculated it step by step "without aha!"—as if their brain were a room slowly being lit with a dimmer switch.

Participants were divided into three groups. The first received only the puzzles. In the second group, two random digits flashed sequentially on the screen before the words appeared, and people had to try to recall those numbers after finishing the puzzle. The third group was identical to the second except that people had to try to remember four digits instead of two.

The purpose of making people remember random numbers was to burden their mind with an unrelated task, which was expected to interfere with conscious problem-solving. "These cognitive resources, this pool that we can tap into to do anything consciously, is limited," Stuyck says. The question was whether insightful thinking would be similarly affected.

Indeed, when participants used analytic thinking—by, for example, generating a phrase such as "con artist," checking whether "con" was a match with "hatch" or "route" and then moving on—they experienced diminishing returns, solving, on average, 16 puzzles when they had no numbers to remember but only 12 puzzles when they had to remember two digits and eight puzzles when they had to remember four.

Yet when people relied on insight, not only was their success rate higher, it was unaffected by the number-recall task. These participants accurately completed between 17 and 19 puzzles, on average, in all three groups. "Whether they don't have the memory task or they have a low-demand memory task or a high-demand memory task, the number of puzzles they solve with insight remains constant," Stuyck says. "That's the most interesting result."

A significant amount of brain activity is unconscious—that is why we can seemingly drive to work automatically and why we are not always aware of the biases that affect our decisions. But cognitive psychologists disagree about whether actual reasoning can occur below the level of awareness. "There is so much debate within the literature," he says.

Stuyck believes that during moments of insight, there is a give-and-take between conscious and unconscious processes. For example, when people attempt the puzzle "pine/crab/sauce," multiple word associations get activated but only the strongest are accessible to the conscious mind. If the correct answer happens to be a weaker association, people may feel stuck, he says, yet below the surface, unbeknownst to them, their mind may be ushering it into awareness. (The answer, by the way, is "apple.")

"Trying to find a creative solution to a problem is like trying to see a dim star at night," says Mark Beeman, a cognitive neuroscientist at Northwestern University and a leading expert on insight, who did not contribute to the new study. "You have to kind of look at it out of the corner of your mind."

Insights typically occur after someone ponders a problem for a while and then puts it aside, Beeman says. Once the foundation has been laid through conscious mental effort, a stroll, nap or distracting task seems to enable a creative breakthrough, one that is typically accompanied by feelings of satisfaction and certainty.

The reason that holding two or four numbers in one's head slows reasoning but does not affect insight-based problem-solving is because turning the spotlight on a faint idea does not seem to require mental exertion, Stuyck says.

Beeman agrees but cautions against directly extrapolating from the new study to the real world. The number-recall task may have been simple enough to serve as a useful diversion, helping puzzlers reach their eureka moment. He doubts the results would hold if people's brainpower was more severely taxed. "I certainly don't want to recommend that people who want to be more creative at work get saddled with more work," he says.

Stuyck's team is about to embark on another puzzle-based insight experiment. This time the researchers will create "virtual lesions" by temporarily deactivating part of the prefrontal cortex, the brain area that we engage to consciously manipulate information. (They will use a harmless, noninvasive method called transcranial magnetic stimulation, which stimulates brain cells using magnetic fields.) This transient impairment is expected to diminish people's success when they use an analytic approach to puzzling, but the question is whether it will affect their ability to solve problems through insight.

—Emily Laber-Warren

Humans Find AI-Generated Faces More Trustworthy Than the Real Thing

Viewers struggle to distinguish images of sophisticated machine-generated faces from actual humans

When TikTok videos emerged in 2021 that seemed to show “Tom Cruise” making a coin disappear and enjoying a lollipop, the account name was the only obvious clue that this wasn’t the real deal. The creator of the “deeptomcruise” account on the social media platform was using “deepfake” technology to show a machine-generated version of the famous actor performing magic tricks and having a solo dance-off.

One tell for a deepfake used to be the “uncanny valley” effect, an unsettling feeling triggered by the hollow look in a synthetic person’s eyes. But increasingly convincing images are pulling viewers out of the valley and into the world of deception promulgated by deepfakes.

The startling realism has implications for malevolent uses of the

Baik Kyeong-hoon, director of the “AI Yoon” team, makes a video clip using AI Yoon, a digital avatar of South Korean presidential candidate Yoon Suk-yeol of the opposition party called the People Power Party. The images on the screen demonstrate how far artificially generated videos, known as deepfakes, have come in the past few years.

Jung Yeon-Je/AFP via Getty Images

technology: its potential weaponization in disinformation campaigns for political or other gain, the creation of false porn for blackmail, and any number of intricate manipulations for novel forms of abuse and fraud. Developing countermeasures to identify deepfakes has turned into an "arms race" between security sleuths on one side and cybercriminals and cyberwarfare operatives on the other.

A new study published in the *Proceedings of the National Academy of Sciences USA* provides a measure of how far the technology has progressed. The results suggest that real humans can easily fall for machine-generated faces—and even interpret them as more trustworthy than the genuine article. "We found that not only are synthetic faces highly realistic, they are deemed more trustworthy than real faces," says study co-author Hany Farid, a professor at the University of California, Berkeley. The result raises concerns that "these faces could be highly effective when used for nefarious purposes."

"We have indeed entered the world of dangerous deepfakes," says Piotr Didyk, an associate professor at the University of Italian Switzerland in Lugano, who was not involved in the paper. The tools used to generate the study's still images are already generally accessible. And although creating equally sophisticated video is more challenging, tools for it will probably soon be within general reach, Didyk contends.

The synthetic faces for this study were developed in back-and-forth interactions between two neural networks, examples of a type known as generative adversarial networks. One of the networks, called a generator, produced an evolving series of synthetic faces like a student working progressively through rough drafts. The other network, known as a discriminator, trained on real images and then graded the generated output by comparing it with data on actual faces.

The generator began the exercise with random pixels. With feedback from the discriminator, it gradually produced increasingly realistic humanlike faces. Ultimately the discriminator was unable to distinguish a real face from a fake one.

The networks trained on an array of real images representing Black, East Asian, South Asian and white faces of both men and women, in contrast with the more common use of white men's faces in earlier research.

After compiling 400 real faces matched to 400 synthetic versions, the researchers asked 315 people to distinguish real from fake among a selection of 128 of the images. Another group of 219 participants got some training and feedback about how to spot fakes as they tried to distinguish the faces. Finally, a third group of 223 participants each rated a selection of 128 of the images for trustworthiness on a scale of one (very untrustworthy) to seven (very trustworthy).

The first group did not do better than a coin toss at telling real faces from fake ones, with an average accuracy of 48.2 percent. The second group failed to show dramatic improvement, receiving only about 59 percent, even with feedback about those participants' choices. The group rating trustworthiness gave the synthetic faces a slightly higher average rating of 4.82, compared with 4.48 for real people.

The researchers were not expecting these results. "We initially thought that the synthetic faces would be less trustworthy than the real faces," says study co-author Sophie Nightingale.

The uncanny valley idea is not completely retired. Study participants did overwhelmingly identify some of the fakes as fake. "We're not saying that every single image generated is indistinguishable from a real face, but a significant number of them are," Nightingale says.

The finding adds to concerns about the accessibility of technology that makes it possible for just about anyone to create deceptive still images. "Anyone can create synthetic content without specialized knowledge of Photoshop or CGI," Nightingale says. Another concern is that such findings will create the impression that deepfakes will become completely undetectable, says Wael Abd-Almageed, founding director of the Visual Intelligence and Multimedia Analytics Laboratory at the University of Southern California, who was not involved in the study. He worries scientists might give up on trying to develop countermeasures to deepfakes, although he views keeping their detection on pace with their increasing realism as "simply yet another forensics problem."

"The conversation that's not happening enough in this research

community is how to start proactively to improve these detection tools," says Sam Gregory, director of programs strategy and innovation at WITNESS, a human rights organization that in part focuses on ways to distinguish deepfakes. Making tools for detection is important because people tend to overestimate their ability to spot fakes, he says, and "the public always has to understand when they're being used maliciously."

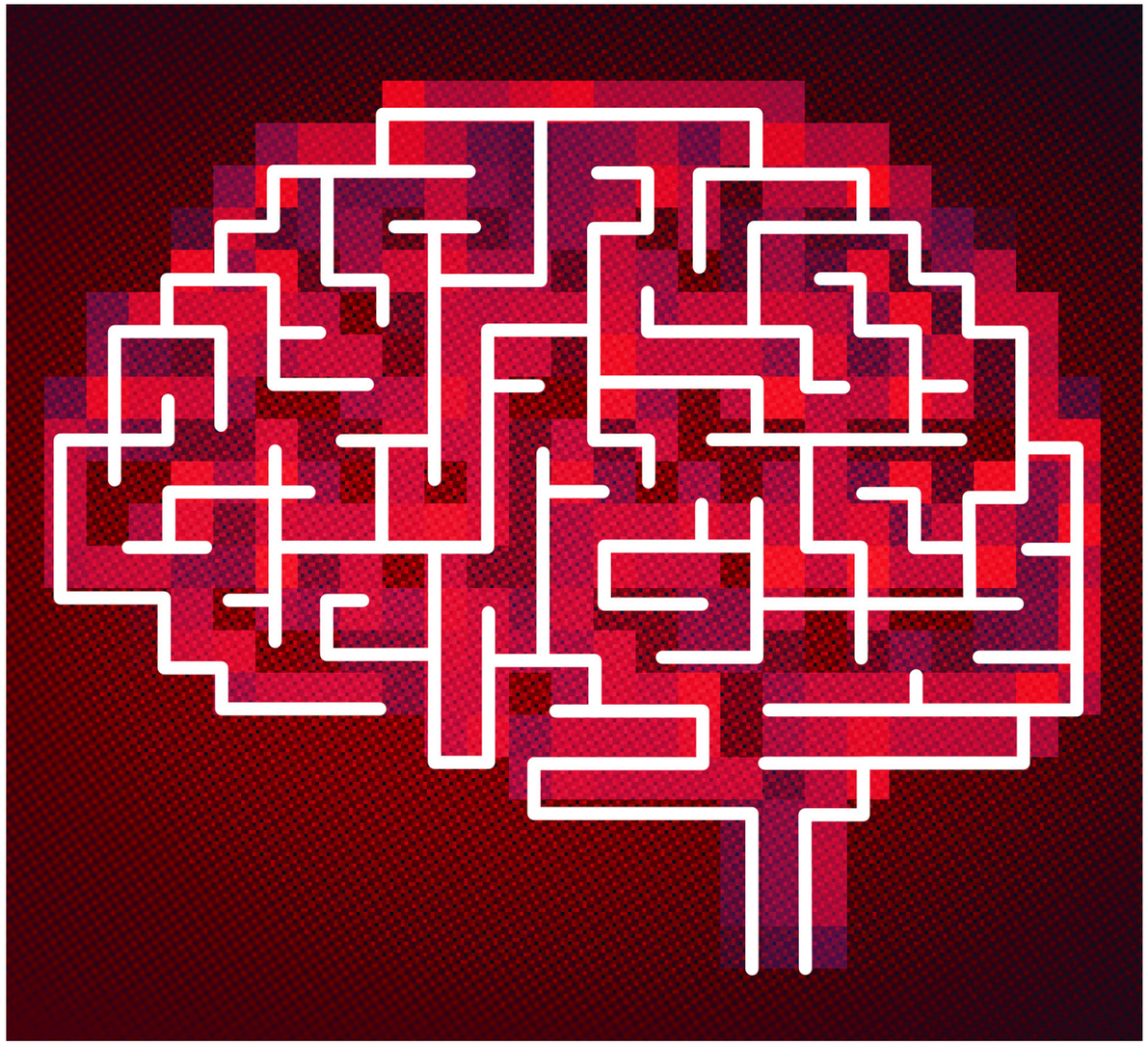
Gregory, who was not involved in the study, points out that its authors directly address these issues. They highlight three possible solutions, including creating durable watermarks for these generated images, "like embedding fingerprints so you can see that it came from a generative process," he says.

The authors of the study end with a stark conclusion after emphasizing that deceptive uses of deepfakes will continue to pose a threat. "We, therefore, encourage those developing these technologies to consider whether the associated risks are greater than their benefits," they write. "If so, then we discourage the development of technology simply because it is possible."

—Emily Willingham

Lego Robot with an Organic "Brain" Learns to Navigate a Maze

The neuromorphic computing device solved the puzzle by working like an animal brain would



Sean Gladwell/Getty Images

In 1997 Carver Mead lectured on an unusual topic for a computer scientist: the nervous systems of animals, such as the humble fly. Mead, a researcher at the California Institute of Technology, described his earlier idea for an electronic problem-solving system inspired by nerve cells, a technique he had dubbed "neuromorphic" computing. A quarter of a century later researchers have designed a carbon-based neuromorphic computing device—essentially an organic robot brain—that can learn to navigate a maze.

A neuromorphic chip memorizes information similarly to the way an animal does. When a brain learns something new, a group of its neurons rearrange their connections so they can communicate more quickly and easily. As a common saying in neuroscience goes, "Neurons that fire together wire together." When a neuromorphic chip learns, it rewires its electric circuits to save the new behavior like a brain does to save a memory.

The idea of brainlike computation has been around for a while. But Paschalis Gkoupidenis of the Max Planck Institute for Polymer Research in Mainz, Germany, and his neuromorphic research team are pioneers in crafting this technology from organic materials. To build their chip, the researchers used long chains of carbon-based molecules

called polymers, which are soft and, in some ways, behave similarly to living tissues. In order to let their material carry an electric charge like real neurons, which are energy-efficient and operate in a watery medium, the scientists coated the organic material with an ion-rich gel. This provided "more degrees of freedom to mimic biological processes," Gkoupidenis says.

Previously some of the researchers who worked with Gkoupidenis's Max Planck group on the new study had shown that organic polymers can record aspects of their past states. This finding had suggested that the polymers can "remember" certain information, such as the sequence of turns required to navigate a maze. So in the recent investigation, the team used organic material to construct transistors—power- and signal-switching devices—and arranged them into a circuit. The resulting "brain chip" can receive sensory signals and use them to adapt to environmental stimuli. After it has learned which way to move, the circuit can send precise motor commands to a robot body. The researchers described their work in *Science Advances* last December.

Once the team members had designed their organic robot brain chip, a maze seemed like the perfect real-world situation in which to test it. This is because success or failure becomes obvious immediately: if the robot finishes the maze, it has clearly learned something—and "if it doesn't, then it didn't learn," explains study co-author Yoeri van de Burgt of Eindhoven University of Technology in the Netherlands.

The team selected a commercial toy robot called Lego Mindstorms EV3, which has two input sensors to register signals for touch and "sight" and two wheels to move around. The scientists equipped the toy with their chip, which could control the direction in which the wheels moved. Then they designed a two-square-meter maze that looked like a two-dimensional honeycomb, filled with potential crossroads, and turned the robot loose in it.

At each crossroad, the machine turned right by default. But each time it eventually hit a side wall, it received a "slap on the nose," as van de Burgt puts it. "Well, that's a fancy [phrase] for basically tuning the resistance a little bit," he adds. This means that when the robot was given a light

"The device learns in the same way we teach kids, giving rewards if they are correct or not rewarding if they are wrong."

—Arindam Basu

human tap or hit a wall, the sensors carried that touch signal to the organic circuit. In response—like neurons rewiring after they receive a corrective stimulus—an electric property of the polymer called resistance was reduced. This allowed more voltage to pass through the polymer, which energized the ions in the material to move to another end of the circuit.

Based on the movement and accumulation of ions, the robot brain could now make a different decision: at the intersection that originally tripped it up, instead of turning right by default, it would now turn left. In this way, the robot learned. With each wrong move, the robot either hit a wall or was gently tapped by the researchers. Then it was moved back to the start of the maze. The robot kept learning which way to turn at each new crossing until, after 16 runs, it finally made it to the exit.

"The device learns in the same way we teach kids, giving rewards if they are correct or not rewarding if they are wrong," says Arindam Basu, a professor of electrical engineering at the City University of Hong Kong, who was not involved in the new study. In this case, the robot performed only binary decisions, turning either left or right. "So it would be interesting to extend the task to choose between multiple decisions," Basu says.

The experiment is "really cool," says Jeffrey Krichmar, a computer scientist at the University of California, Irvine, who was also not involved in the study. The robot was allowed to make mistakes and amend them later on, Krichmar says. The researchers did not preprogram its future steps, he notes, "but they let the whole training be a part of its circuit."

Although the experiment demonstrated the learning power of an organic control chip, the machine's ability to sense its surroundings and move still relied on the inorganic components of the toy robot. "Next

steps could be replacing them with organic counterparts," says Robert Nawrocki, an assistant professor at Purdue University's School of Engineering Technology, another researcher who was not involved in the study. An all-organic device would be advantageous because it could be biocompatible—potentially allowing it to be implanted into the human body, for example. If organic neuromorphic devices reach that point, Nawrocki suggests, they may help in treating certain diseases and injuries to the nervous system. In the brain, he adds, neuromorphic implants could allow humans to control powered exoskeletons as well.

The organic neuromorphic chip also has the advantage of requiring less power than a standard chip. In order to switch, the organic transistors require only half a volt of electricity—about 20 times less than their silicon counterparts with similar dimensions, according to the authors of the new study. Because power is proportional to voltage, this means the entire system has lower power requirements. The neuromorphic chip is also relatively cheap to produce and comparatively simpler than a silicon system, van de Burgt says.

Such a low-power system could have many applications. For instance, it might help robots work for long hours at remote places on Earth—or even on another planet—without constantly needing to recharge, Krichmar says. Fifty or 100 years down the line, Nawrocki says, "we may have ultra-low-power autonomous robots, like artificial insects, that could even pollinate crops."

—Saugat Bolakhe

The Personality Trait "Intolerance of Uncertainty" Causes Anguish during COVID

High levels of it have put people at risk of emotional problems

By Francine Russo

Aleli Dezmen/Getty Images

Francine Russo is a journalist specializing in psychology and behavior. She is author of *Love after 50: How to Find It, Enjoy It, and Keep It* (Simon and Schuster, 2021).

Anxiety disorders are the most common type of mental disorders in the U.S. But a simple diagnosis of generalized anxiety disorder may not capture the specifics of what bothers some people. A subgroup of anxiety sufferers may experience extreme distress when confronting the inherent uncertainties that turn up in any life circumstance, whether helping a relative with a severe illness or choosing a new route to work that is safe and easy to navigate.

Such people may respond to their feelings by leaving nothing to chance. At work, they appear polished and prepared when giving a presentation because they consider every question that could be posed by colleagues beforehand and memorize possible answers in the days leading up to a meeting. Still, all of the prep work may do little to relieve feelings of painful anxiety.

Psychologists, though, are learning new ways to treat these sufferers, who can be identified through their answers to a psychological measurement known as the intolerance of uncertainty scale (IUS). Patients can then benefit from specialized treatment.

These patients are typical of the ones psychologist Keith Bredemeier sees at the University of Pennsylvania's Center for the Treatment and Study of Anxiety. When encountering patients with a high score on the IUS, Bredemeier may explicitly target enhancing their comfort levels with life's unpredictability as a treatment goal. Because therapy is adapted to patients' salient personality traits, treatment for uncertainty distress may be added to their treatment plans just as treatments for eating disorders, for example, may focus on clients' perfectionism. And therapy for obsessive-compulsive disorder may concentrate on patients' inflated sense of responsibility.

Difficulty dealing with uncertainty was first identified in the early 1990s as a distinguishable personality trait. It is one we all have to some degree, but many of us have it at an elevated level. Like perfectionism or rigidity, it is really a predisposition, not a diagnosable disorder. People who have high levels of perfectionism, for example, are at greater risk of developing anorexia. And someone with a high level of intolerance of uncertainty (IU) may end up developing an anxiety disorder.

To cope, a person may live along a narrow, predictable track. Everything may seem fine to them on the surface, but their risk for developing anxiety, depression or emotional distress is higher—especially if something such as, say, a pandemic wreaks havoc on a carefully planned life.

In the decades since the IUS was developed, researchers have found it useful for understanding why some patients are anxious, devising targeted therapies and assessing a patient's progress. In psychology laboratories, investigators have probed how uncertainty affects people's brain and behavior. Clinicians have used the concept to develop programs that teach parents of autistic children strategies to help their children better tolerate uncertainty. And tourism specialists have delved into which clients might prefer guided tours instead of unguided ones. Most of all, because the pandemic blew away a sense of predictability in everyday life, the concept has sparked an explosion of research globally to find out how those who typically feel this type of distress are faring in these uncertain times and what might be done to help them.

IT BEGAN WITH A HUNCH

In the 1990s Mark Freeston and Michel Dugas were part of a team at Laval University in Quebec looking into generalized anxiety disorder. The focus in the field was on worry. The thinking at the time "was that worry was some form of problem-solving gone wrong or a problem-solving deficit," notes Freeston, who is now at Newcastle University in England. But Freeston and his colleagues saw something different in their patients' behavior. "They knew how to solve problems, but something was getting in the way," he says. The team hypothesized that anxious people might have a negative reaction to uncertainty. Following a "clinical hunch," he says, the group developed the IUS and tested it out.

When filling out this questionnaire, people indicated how they might react to statements such as "Unforeseen

events upset me greatly" and "It frustrates me not having all the information I need." The scale accurately assessed subjects' reactions—cognitive, emotional and behavioral—to uncertain situations in which they felt they did not know vital information or could not control the future.

"They knew how to solve problems, but something was getting in the way."
—Mark Freeston

EVOLUTION AND FEAR OF THE UNKNOWN

For humans and other animals, fear of uncertainty is a default state, says health psychologist Jos F. Brosschot of Leiden University in the Netherlands. Carry your cat into an unfamiliar empty room, he suggests. No fierce dog or hostile human is there, but there is also no obvious place to hide. Without a safe spot, the animal might be apt to claw at your chest in terror. "In the wild," Brosschot and his colleagues wrote in a 2018 paper, "organisms have survived not by waiting for more evidence of threat but instead by erring on the side of caution.... Those who fled at the first sign of unsafety continued to live and pass their genes."

From birth, humans have to carefully learn the cues that signal safety. For a toddler, safety is wherever their caregiver is. Over time, if we grow up in a secure environment with supportive parents, we learn to feel safe when there is no obvious danger. We become better able to tolerate uncertainty. But for those of us who grew up abused, neglected or otherwise deprived of feeling safe, uncertainty is threatening.

UNCERTAINTY IN THE LAB

At the University of Reading in England, psychologist Jayne Morriss has subjected volunteers in her lab to unpleasant experiences that they may or may not be able to predict, from a mild electric shock to a terrifying scream. Before doing so, she already assessed them with the usual psychological tests, including the IUS. She also ascertained their thresholds for receiving a mild electric shock. Then, as they sat in front of a computer that told them whether, when or if they would receive a shock (or hear a scream), she measured their physiological responses with a magnetic resonance imaging scanner, skin conductance sensors or registers of startle response, depending on the study. Invariably, people high in IU show greater physiological distress.

One of her studies, published last year and entitled, in part, "I Told You It Was Safe," produced intriguing results. The subjects were told that they would receive a shock at a certain time, at an unknown time, or not at all—or, more emphatically, that they definitely would not get shocked. The surprising result is that those with high IU scores showed the greatest physiological distress during the certain-to-be-safe period.

This seems counterintuitive, yet it is easy to explain. Those of us who grew up with unpredictable danger or inconsistent safety are ever vigilant for harm. "People consistently high in IU have trouble recognizing when they are safe," Freeston says. "Just telling them it's safe isn't enough." In fact, Morriss has shown in other studies that subjects with high IU need a greater number of exposures to a now safe scenario that was previously unsafe before they have no distress response. In other words, they have more difficulty updating their perception of safety.

TAILORING THERAPY

As intolerance of uncertainty has begun to be studied as a separate trait from a tendency to worry, psychologists have identified typical behaviors—often unconstructive ones—that people use to tamp down their distress at not knowing. They overprepare, perhaps memorizing answers to all the possible questions anticipated for an upcoming presentation. Some collect every bit of information they can find online and offline. They constantly seek reassurance from others and look for media sources they can trust. Or they avoid situations with unknown outcomes. If they do not know how they will do on a test, they may avoid looking at their textbooks or procrastinate. They may impulsively make a choice, even a bad one, in order to resolve their uncertainty about something. They may also decide that they know an answer and close their minds to new information.

Bredemeier adapts treatments for these patients at his clinic. To help a client feel more comfortable with uncertainty, he first has them list situations that feel mildly to intensely uncomfortable. Let's say someone dislikes ordering from a new restaurant without first reading reviews or avoids taking a different route to work. The worst situation of all would be delegating an important task at work. The person just cannot do it.

In response, the therapist asks a client to do each task, starting with the easiest one first. A feeling of uncertainty grows, but the person stays aware of thoughts and feelings and reflects on the outcome. Maybe the client wishes they had ordered the usual takeout. Maybe they have found a favorite new restaurant. The outcome is less important than becoming more comfortable with some unpredictability. After a series of these experiments, the client is likely to score lower on IU and eventually reduce inflexible behaviors.

COVID: UNCERTAINTY IN REAL TIME

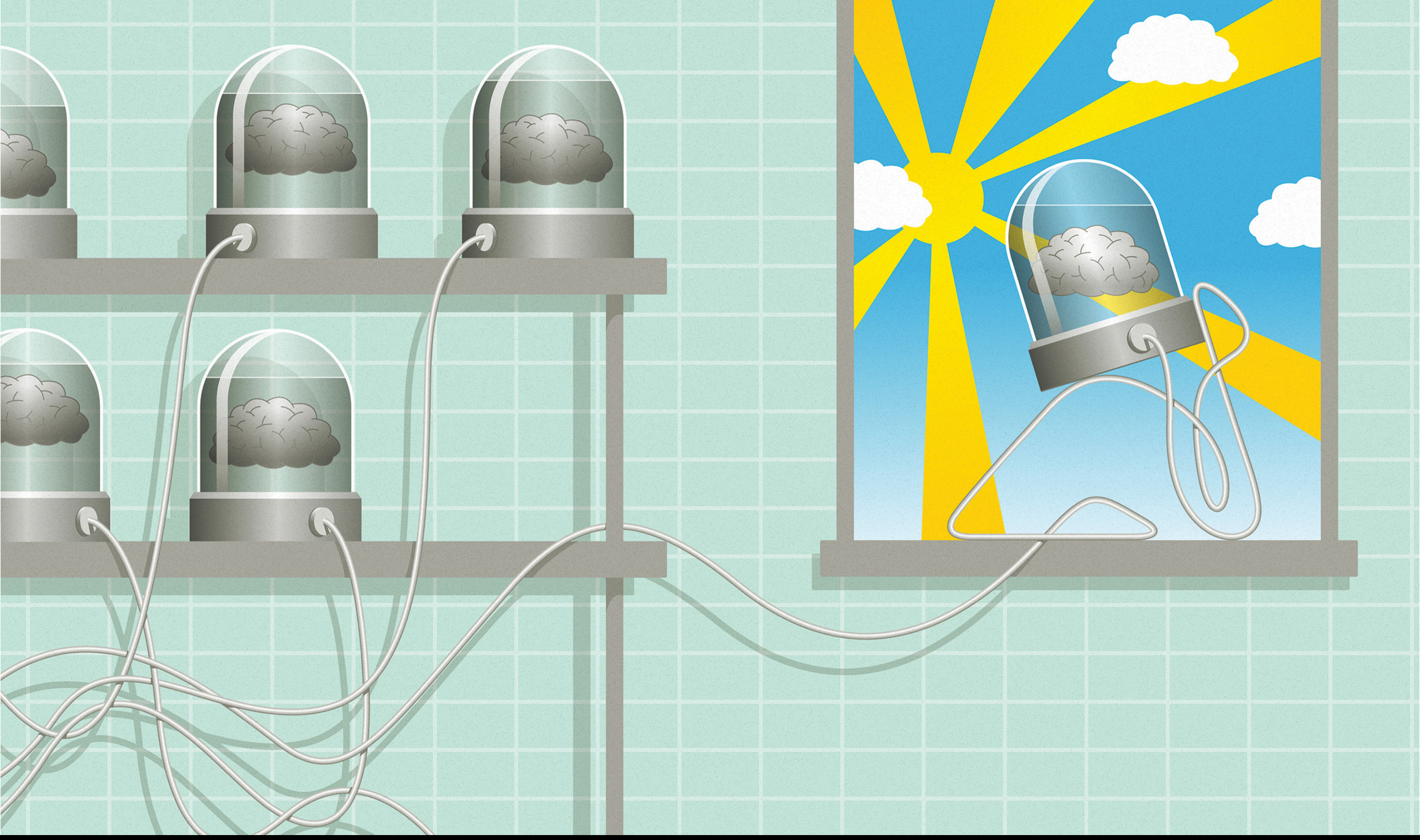
When the pandemic hit, none of us knew from day to day what would happen. No one knew how infections—or the threat of them—would affect work, school or travel. Nobody liked the unpredictability. Dozens of studies worldwide showed that people high in IU were at greatest risk of emotional problems.

A study published in January 2022 is especially noteworthy. Two years before COVID emerged, a team at the University of Illinois at Chicago used two methods to measure volunteers' uncertainty intolerance during predictable and unpredictable shocks. The researchers administered the IUS self-report questionnaire before the experiment. And during it, they monitored subjects' neural response with functional magnetic resonance imaging.

Two years later, at the height of the pandemic, the researchers asked these same volunteers detailed questions about their emotional reactions to the crisis. Having higher self-reported IU or greater activity in a brain area called the anterior insula during imaging independently predicted an increase in anxiety, depression or emotional distress.

Therapists have begun to target their patients' uncertainty intolerance to help them through the pandemic because COVID's unpredictability exacerbates classic IU behaviors in some people. Some read everything they can find on the Internet, wash their hands incessantly and rarely leave home. Others refuse to alter their routines even if they are putting themselves or others at risk. There are endless permutations of dealing with this continuing state of just not knowing.

As Bredemeier says, "All of us like to feel certain. It's just a question of how much distress it causes us. Intolerance of uncertainty is a matter of degree." **M**



Can Lab-Grown Brains Become Conscious?

A handful of experiments are raising questions about whether clumps of cells and disembodied brains could be sentient and how scientists would know if they were *By Sara Reardon*

Thomas Fuchs

Sara Reardon is a freelance journalist based in Bozeman, Mont. She is a former staff reporter at *Nature*, *New Scientist* and *Science* and has a master's degree in molecular biology.

In Alysson Muotri's laboratory, hundreds of miniature human brains, the size of sesame seeds, float in petri dishes, sparking with electrical activity. These tiny structures, known as brain organoids, are grown from human stem cells and have become a familiar fixture in many labs that study the properties of the brain. Muotri, a neuroscientist at the University of California, San Diego, has found some unusual ways to deploy his. He has connected organoids to walking robots, modified their genomes with Neandertal genes, launched them into orbit onboard the International Space Station and used them as models to develop more humanlike artificial-intelligence systems. Like many scientists, Muotri temporarily pivoted to studying COVID, using brain organoids to test how drugs perform against the SARS-CoV-2, the COVID-causing coronavirus.

But one experiment has drawn more scrutiny than the others. In August 2019 Muotri's group published a paper in *Cell Stem Cell* reporting the creation of human brain organoids that produced coordinated waves of activity resembling those seen in premature babies. The waves continued for months before the team shut the experiment down.

This type of brain-wide, coordinated electrical activity is one of the properties of a conscious brain. The team's finding led ethicists and scientists to raise a host of moral and philosophical questions about whether organoids should be allowed to reach this level of advanced development, whether "conscious" organoids might be entitled to special treatment and rights not afforded to other clumps of cells, and the possibility that consciousness could be created from scratch.

The idea of bodiless, self-aware brains was already on the minds of many neuroscientists and bioethicists. Just a few months earlier a team at Yale University announced that it had at least partially restored life to the brains of pigs that had been killed hours before. By removing the brains from the pigs' skulls and infusing them with a chemical cocktail, the researchers revived the neurons' cellular functions and their ability to transmit electrical signals.

Other experiments, such as efforts to add human neurons to mouse brains, have raised questions, with some scientists and ethicists arguing that these experiments should not be allowed.

The studies set the stage for a debate between those who want to avoid the creation of consciousness and those who see complex organoids as a means to study and test treatments for human diseases. Muotri and many other neuroscientists think that human brain organoids could be the key to understanding uniquely human conditions such as autism and schizophrenia, which are impossible to study in detail in mouse models. To achieve this goal, Muotri says, he and others might need to deliberately create consciousness.

Researchers have been calling for a set of guidelines, similar to those used in animal research, to address the humane use of brain organoids and other experiments that could achieve consciousness. In June 2020 the U.S. National Academies of Sciences, Engineering and Medicine began a study with the aim of outlining the potential legal and ethical issues associated with brain organoids and human-animal chimeras.

The concerns over lab-grown brains have also highlighted a problem: neuroscientists have no agreed-on way to define and measure consciousness. Without a working definition, ethicists worry that it will be impossible to stop an experiment before it crosses a line.

The current crop of experiments could force the issue. If scientists become convinced that an organoid has gained consciousness, they might need to hurry up and agree on a theory of how that happened, says Anil K. Seth, a cognitive neuroscientist at the University of Sussex in England. But, he says, if one person's favored theory deems the organoid conscious, whereas another's does not, any confidence that consciousness has been attained vanishes: "Confidence largely depends on what theory we believe in. It's a circularity."

SENTIENT STATES

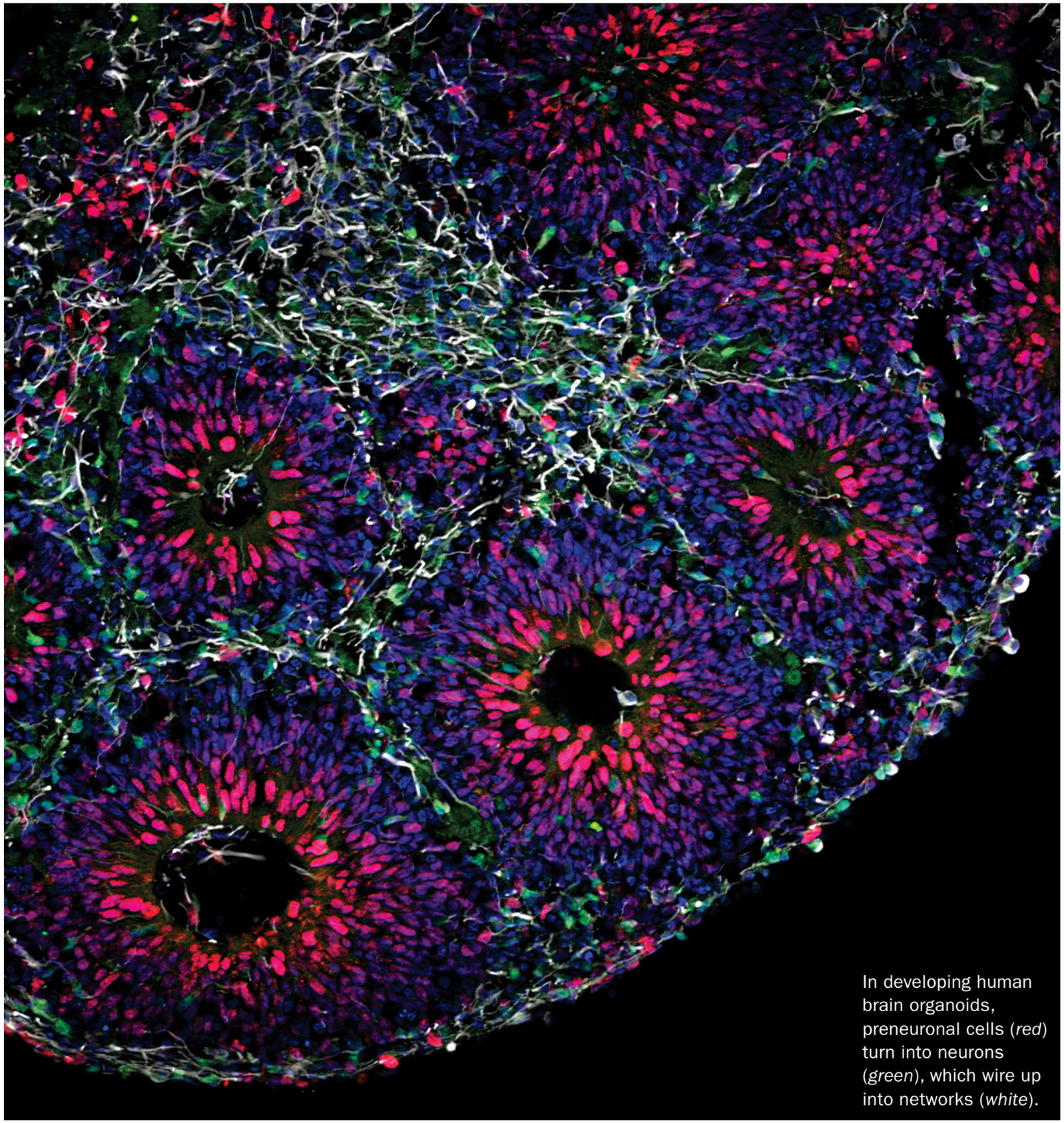
Creating a conscious system might be a whole lot easier than defining it. Researchers and clinicians define consciousness in many different ways for various purposes, but it is hard to synthesize them into one neat operational definition that could be used to decide on the status of a lab-grown brain.

Physicians generally assess the level of consciousness in patients in a vegetative state on the basis of whether the person blinks or flinches in response to pain or other stimuli. Using electroencephalogram (EEG) readings, for instance, researchers can also measure how the brain responds when it is zapped with an electrical pulse. A conscious brain will display much more complex, unpredictable electrical activity than one that is unconscious, which responds with simple, regular patterns.

But such tests might not adequately probe whether a person lacks consciousness. In brain-imaging studies of people who are in a coma or a vegetative state, scientists have shown that unresponsive individuals can display some brain activity reminiscent of consciousness—such as activity in motor areas when asked to think about walking.

In any case, standard medical tests for consciousness are difficult to apply to brain cells grown in dishes or to disembodied animal brains. When Muotri suggested that his organoids' firing patterns were just as complex as those seen in preterm infants, people were unsure what to make of that. Some researchers do not consider the brain activity in a preterm infant to be complex enough to be classed as conscious. And organoids cannot blink or recoil from a painful stimulus, so they would not pass the clinical test for consciousness.

In contrast, it is much more likely that an intact brain from a recently killed pig has the necessary structures for consciousness, as well as wiring created by memories and experiences the animal had while it was alive. "Thinking



In developing human brain organoids, preneuronal cells (*red*) turn into neurons (*green*), which wire up into networks (*white*).

Muotri Lab/University of California, San Diego

about a brain that has been filled with all this, it is hard to imagine that brain would be empty," says Jeantine Lunshof, a philosopher and neuroethicist at Harvard University. "What they can do in terms of thinking, I don't know, but it's for sure not zero," Lunshof says. Bringing a dead brain back to a semblance of life, as the Yale team did, might have the potential to restore a degree of consciousness, although the scientists took pains to avoid this by using chemical blocking agents that prevented brain-wide activity.

Researchers agree that they need to take the possibilities raised by these studies seriously. In October 2019 U.C.S.D. held a conference of about a dozen neuroscientists and philosophers, together with students and members of the public, with the intention of establishing and publishing an ethical framework for future experiments. But the paper was delayed for months, partly because several of the authors could not agree on the basic requirements for consciousness.

"If we did stop all of this research because of the philosophical thought experiment, that would be very detrimental to actual human beings who do need some new treatment."

—Madeline Lancaster

INCREASINGLY COMPLEX

So far nobody has created consciousness in the lab, say scientists and ethicists who study the issue. But they are asking themselves what to watch out for and which theories of consciousness might be most relevant. According to an idea called integrated information theory, for example, consciousness is a product of how densely neuronal networks are connected across the brain. The more neurons that interact with one another, the higher the degree of consciousness—a quantity known as phi. If phi is greater than zero, the organism is considered conscious.

Most animals reach this bar, according to the theory. Christof Koch, who serves on *Scientific American*'s board of advisers and is chief scientist of the MindScope Program at the Allen Institute for Brain Science, doubts any existing organoid could achieve this threshold but concedes that a more advanced one might.

Other competing theories of consciousness require sensory input or coordinated electrical patterns across multiple brain regions. An idea known as global workspace theory, for instance, posits that the brain's prefrontal cortex functions as a computer, processing sensory inputs and interpreting them to form a sense of being. Because organoids do not have a prefrontal cortex and cannot receive input, they cannot become conscious. "Without input and output, the neurons may be talking with each other, but that doesn't necessarily mean anything like human thought," says Madeline Lancaster, a developmental biologist at the University of Cambridge.

Connecting organoids to organs, however, could be a fairly simple task. In 2019 Lancaster's team grew human brain organoids next to a mouse spinal column and back muscle. When nerves from the human organoid connected with the spinal column, the muscles began to spontaneously contract.

Most organoids are built to reproduce only one part of the brain—the cortex. But if they develop long enough and with the right kinds of growth factor, human stem cells spontaneously re-create many different parts of the brain, which then begin coordinating their electrical activity. In a study published in 2017, molecular biologist Paola Arlotta of Harvard coaxed stem cells to develop into brain organoids composed of many different cell types, including light-sensitive cells like those found in the retina. When exposed to light, neurons in the organoids began firing. But the fact that these cells were active does not mean the organoids could see and process visual information, Arlotta says. It simply means that they could form the necessary circuits.

Arlotta and Lancaster think their organoids are too primitive to be conscious because they lack the anatomical structures necessary to create complex EEG patterns. Still, Lancaster admits that for advanced organoids, it depends on the definition. "If you thought a fly was conscious, it's conceivable that an organoid could be," she says.

Lancaster and most other researchers think that something like a revitalized pig brain would be much more likely to achieve consciousness than an organoid. The team that did the work on the pig brains, led by neuroscientist Nenad Sestan, was trying to find new ways to revitalize organs, not to create consciousness. The researchers were able to get individual neurons or groups of them to fire and were careful to try to avoid the creation of widespread brain waves. Still, when Sestan's team members saw what looked like coordinated EEG activity in one of the brains, they immediately halted the project. Even after a neurology specialist confirmed that the pattern was not consistent with consciousness, the group anesthetized the brains as a precautionary measure.

Sestan also contacted the U.S. National Institutes of Health for guidance on how to proceed. The agency's neuroethics panel, including Lunshof and Insoo Hyun, a bioethicist at Case Western University, assessed the work and agreed that Sestan should continue to anesthetize the brains. But the panel has not settled on more general regulations and does not routinely require a bioethics assessment for organoid proposals, because its members think that consciousness is unlikely to arise. The NIH has not arrived at a definition of consciousness, either. "It's so

flexible, everyone claims their own meaning," Hyun says. "If it's not clear we're talking about the same thing, it's a big problem for discourse."

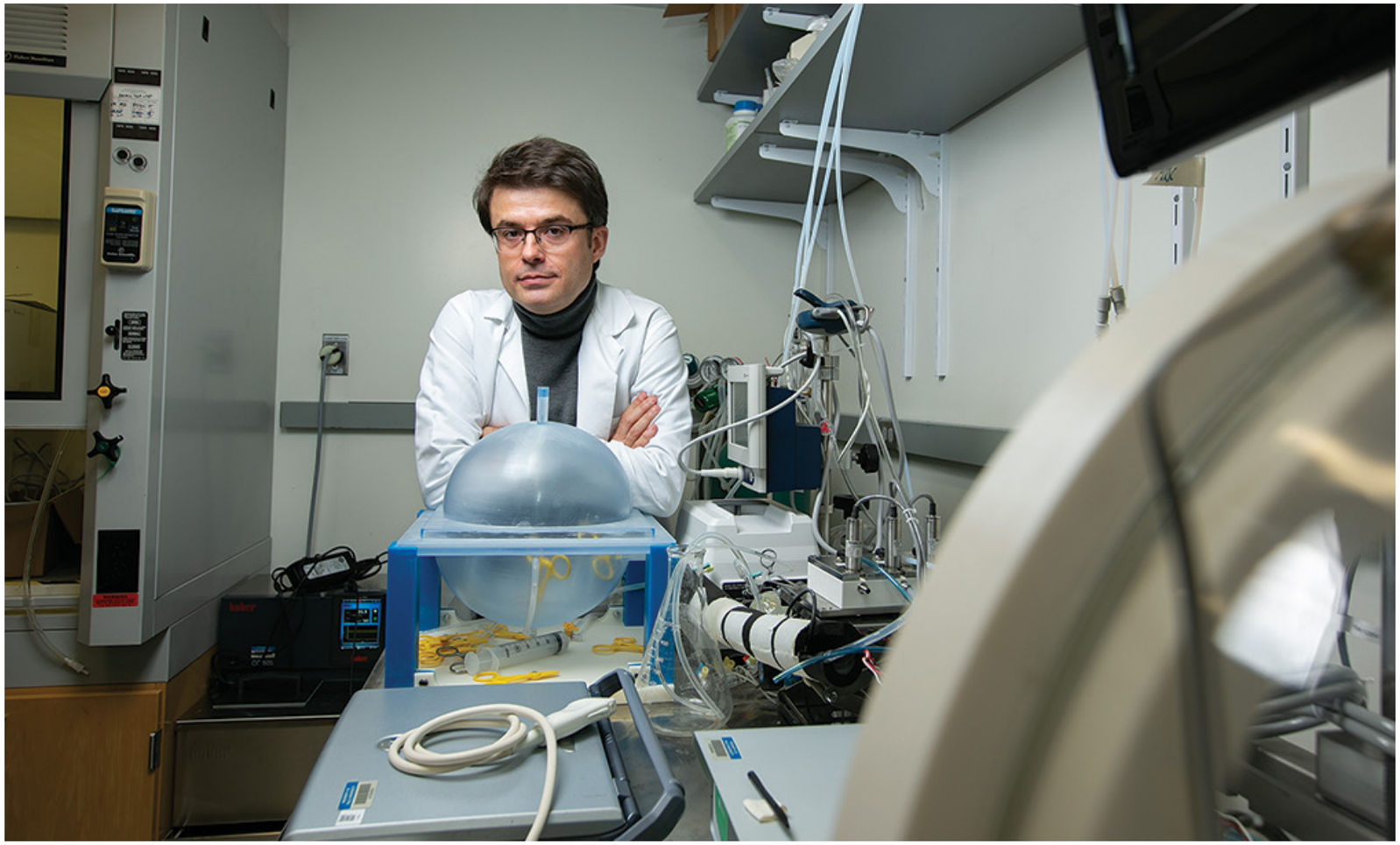
FUZZY DEFINITIONS

Some think it is futile to even try to identify consciousness in any sort of lab-maintained brain. "It's just impossible to say meaningful things about what these bunches of brain cells could think or perceive, given we don't understand consciousness," says Steven Laureys, a neurologist at the University of Liège in Belgium, who pioneered some of the imaging-based measures of consciousness in people in a vegetative state. "We shouldn't be too arrogant." Further research should proceed very carefully, he says.

Laureys and others point out that the experience of an organoid is likely to be very different from that of a preterm infant, an adult human or a pig and would not be directly comparable. Furthermore, the structures in an organoid might be too small to have their activity measured accurately, and similarities between the EEG patterns of organoids and of preterm baby brains could be coincidental. Other scientists who work on brain organoids also caution against making assumptions about the link between activity patterns in organoids and consciousness.

"This system is not the human brain," says Sergiu Pasca, a neuroscientist at Stanford University. "They're made out of neurons. Neurons have electrical activity, but we have to think carefully about how to compare them."

Muotri wants his organoid systems to be comparable, in at least some ways, with human brains so that he can study human disorders and find treatments. His motivation is personal: his teenage son has epilepsy and autism. "He struggles hard in life," Muotri says. Brain organoids are a promising avenue because they recapitulate the earliest stages of brain wiring, which are impossible to study as a human embryo develops. But studying human brain disorders without a fully functioning brain, he says, is like studying a pancreas that does not produce insulin. "To get there, I need a brain organoid model that really resembles a human brain. I might need an organoid that becomes conscious."



Neuroscientist Nenad Sestan used the BrainEx platform to restore neural activity in disembodied pig brains.

Jesse Winter

Muotri says he is agnostic about which definition to use to decide whether an organoid reaches consciousness. At some point, he says, organoids might even be able to help researchers answer questions about how brains produce conscious states. For instance, mathematician Gabriel Silva of U.C.S.D. is studying neural activity in Muotri's organoids to develop an algorithm that describes how the brain generates consciousness. The goal of his project, which is partially funded by Microsoft, is to create an artificial system that works like human consciousness.

At the moment, there are no regulations in the U.S. or in Europe that would stop a researcher from creating consciousness. The National Academies panel released a report in April 2021 outlining the latest research and what it views as appropriate oversight. Members weighed in on questions such as whether to obtain people's consent to develop their cells into brain organoids and how to study and dispose of organoids humanely. The International Society for Stem Cell Research has also released organoid guidelines but is not addressing consciousness, because it does not think the science is there yet.

Hyun says that the NIH neuroethics panel has not yet seen any proposals to create complex, conscious organoids that would necessitate new guidelines. And Muotri says he does not know of anyone else deliberately trying to create conscious organoids either, although a sufficiently complex organoid could, by some definitions, reach that status accidentally.

Still, Muotri and others say they would welcome some stricter guidelines. These could include requiring scientists to justify the number of human brain organoids they use, to use them only for research that cannot be done in any other way, to restrict the amount of pain that can be inflicted on them, and to dispose of them humanely.

Having such advice in place ahead of time would help researchers weigh the costs and benefits of creating conscious entities. And many researchers emphasize that such experiments have the potential to yield important insights. “There are truly conscious people out there with neurological disorders with no treatments,” Lancaster says. “If we did stop all of this research because of the philosophical thought experiment,” she adds, “that would be very detrimental to actual human beings who do need some new treatment.”

Treatments could still, however, be tested in brain organoids made using mouse stem cells or in regular animal models. Such experiments could also inform discussions about the ethical use of human organoids. For instance, Hyun would like to see researchers compare the EEG patterns of mouse brain organoids with those of living mice, which might indicate how well human organoids recapitulate the human brain.

For his part, Muotri sees little difference between working on a human organoid and using a lab mouse. “We work with animal models that are conscious, and there are no problems,” he says. “We need to move forward, and if it turns out they become conscious, to be honest, I don’t see it as a big deal.” **M**

The Pandemic Generation

Child-development researchers are investigating whether the pandemic is shaping early brain development and behavior

By Melinda Wenner Moyer

A teacher in a biosecurity suit gives a lesson to a girl in her home in Cali, Colombia.

Luis Robayo/AFP via Getty Images

Melinda Wenner Moyer, a contributing editor at *Scientific American*, is author of *How to Raise Kids Who Aren't Assholes: Science-Based Strategies for Better Parenting—From Tots to Teens* (G. P. Putnam's Sons, 2021). She wrote about the challenges of teaching U.S. students how to separate fact from fiction in the February 2022 issue.

LIKE MANY PEDIATRICIANS, Dani Dumitriu braced herself for the impact of SARS-CoV-2, the COVID-causing coronavirus, when it first surged in her wards. She was relieved when most newborn babies at her hospital who had been exposed to COVID seemed to do just fine. Knowledge of the effects of Zika and other viruses that can cause birth defects meant that doctors were looking out for problems.

But hints of a more subtle and insidious trend followed close behind. Dumitriu and her team at the NewYork-Presbyterian Morgan Stanley Children's Hospital in New York City had more than two years of data on infant development—since late 2017, they had been analyzing the communication and motor skills of babies up to six months old. Dumitriu thought it would be interesting to compare the results from babies born before and during the pandemic. She asked her colleague Morgan Firestein, a postdoctoral researcher at Columbia University, to assess whether there were neurodevelopmental differences between the two groups.

A few days later Firestein called Dumitriu in a panic. "She was like, 'We're in a crisis, I don't know what to do, because we not only have an effect of a pandemic, but it's a significant one,'" Dumitriu recalled. She was up most of that night, poring over the data. The infants born during the pandemic scored lower, on average, on tests of gross-motor, fine-motor and communication skills compared with those born before it (both groups were assessed by their parents using an established questionnaire). It didn't matter whether their birth parent had been infected with the virus or not; there seemed to be something about the environment of the pandemic itself.

Dumitriu was stunned. "We were like, oh, my God," she recalled. "We're talking about hundreds of millions of babies."

Although children have generally fared well when infected with SARS-CoV-2, preliminary research suggests that pandemic-related stress during pregnancy could be negatively affecting fetal brain development in some children. Moreover, frazzled parents and carers might be interacting differently or less with their young children in ways that could affect a child's physical and mental abilities.

Lockdowns—which have been crucial for controlling the spread of the coronavirus—have isolated many young families, robbing them of playtime and social interactions. Stressed out and stretched thin, many carers also haven't been able to provide the one-on-one time that babies and toddlers need.

"Everyone wants to document how this is impacting child development and parent-child relationships and peer relationships," says James Griffin, chief of the Child Development and Behavior Branch at the Eunice Kennedy Shriver National Institute of Child Health and Human Development in Bethesda, Md. "Everyone has concerns."

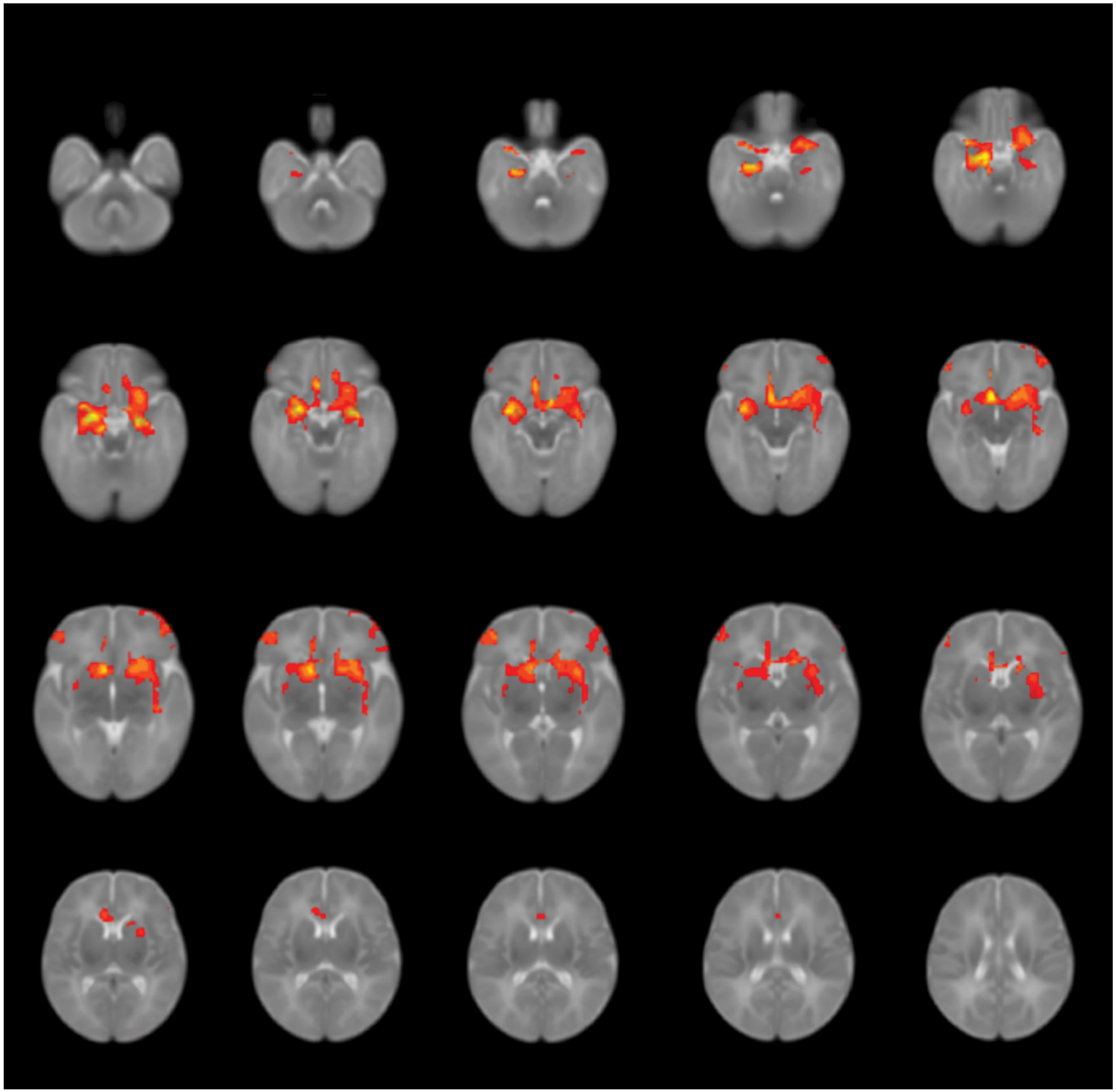
Some of the teams looking into these issues around the world are starting to publish their findings. New studies have begun. Firm answers are hard to come by, not least because many child-development research laboratories shut down during the pandemic.

Some babies born during the past two years might be experiencing developmental delays, whereas others might have thrived, if carers were at home for extended periods and there were more opportunities for siblings to interact. As with many aspects of health during the pandemic, social and economic disparities have a clear role in who is affected the most. Early data suggest that the use of masks has not negatively affected children's emotional development. But prenatal stress might contribute to some changes in brain connectivity. The picture is evolving, and many studies have not yet been peer-reviewed.

Some researchers propose that many of the children falling behind in development will be able to catch up without lasting effects. "I do not expect that we're going to find that there's a generation that has been injured by this pandemic," says Moriah Thomason, a child and adolescent psychologist at the New York University Grossman School of Medicine.

A PRECIPITOUS DROP IN PLAY

One facility that managed to stay open during the COVID-19 pandemic was Brown University's Advanced



Baby Imaging Lab. There Sean Deoni, a medical biophysicist, and his colleagues use magnetic resonance imaging (MRI) and other techniques to study how environmental factors shape brain development in infants.

Although the pandemic changed how they conducted their research—fewer visitors and more cleaning—they continued inviting babies to their lab, to track motor, visual and language skills as part of a seven-year National Institutes of Health study on early childhood development and its effects on later health.

But as the pandemic progressed, Deoni began hearing worrying comments from his colleagues. "What our staff began to tell me, anecdotally, was 'Man, it's taking these kids a lot longer to get through these assessments,'" Deoni recalled.

He was mystified, so asked his researchers to plot and compare the yearly averages and variances from the infants' neurodevelopmental scores. That's when they discovered that the scores during the pandemic were much worse than those from previous years. "Things just began sort of falling off a rock the tail end of last year and the beginning part of this year," he said in late 2021.

When they compared results across participants, the pandemic-born babies scored almost two standard deviations lower than those born before it on a suite of tests that measure development in a similar way to IQ tests. They also found that babies from low-income families experienced the largest drops, that boys were more affected

Brain scans showing average connectivity patterns between the amygdala and other regions in infants. Pandemic-related stress during pregnancy weakened connections in some babies.

Kathryn Manning

than girls and that gross-motor skills were affected the most.

At first, Deoni assumed that selection bias was at play: perhaps the families who made the effort to come in for testing during the pandemic were those whose children were at risk of developmental problems or were already showing them. But over time he grew convinced that selection bias wasn't explaining the findings, because the children coming in did not have different backgrounds, birth outcomes or socioeconomic statuses compared with previous participants.

These effects appeared drastic, but some researchers argue that they are not necessarily predictive of long-term problems. "IQ, as babies, doesn't predict much," says Marion van den Heuvel, a developmental neuropsychologist at Tilburg University in the Netherlands. "It's really hard to say anything about what that will mean for their future." She points to a study showing that Romanian girls who started life in orphanages but were then adopted by foster families before 2.5 years of age were less likely to have psychiatric problems at 4.5 years of age than were girls who remained in institutional care. That situation is different from a pandemic, but it suggests that babies could make up for hardship once restrictions are lifted.

Worryingly, however, Deoni has found that the longer the pandemic has continued, the more deficits children have accumulated. "The magnitude is massive—it's just astonishing," Deoni says of the findings, which are now under revision in *JAMA Pediatrics*.

When Deoni first posted his results on a preprint server, there was a flurry of worrying media coverage—and backlash from the research community. There was "a real concern about the fact that these results were being put out without proper peer review," Griffin says.

But assuming the findings do have merit, why might babies born during the COVID-19 pandemic be experiencing significant cognitive—and especially motor—deficits? Deoni suspects that the problems stem from a lack of human-to-human interactions. In follow-up research that has not yet been published, he and his team have recorded parent-child interactions at home, finding that the number of words spoken by parents to their children, and vice versa, in the past two years has been lower than in previous years. He also suspects that babies and toddlers are not getting as much gross-motor practice as usual because they aren't regularly playing with other children or going to playgrounds. "And the unfortunate thing is that those skills kind of lay the foundation for all the other skills," he says.

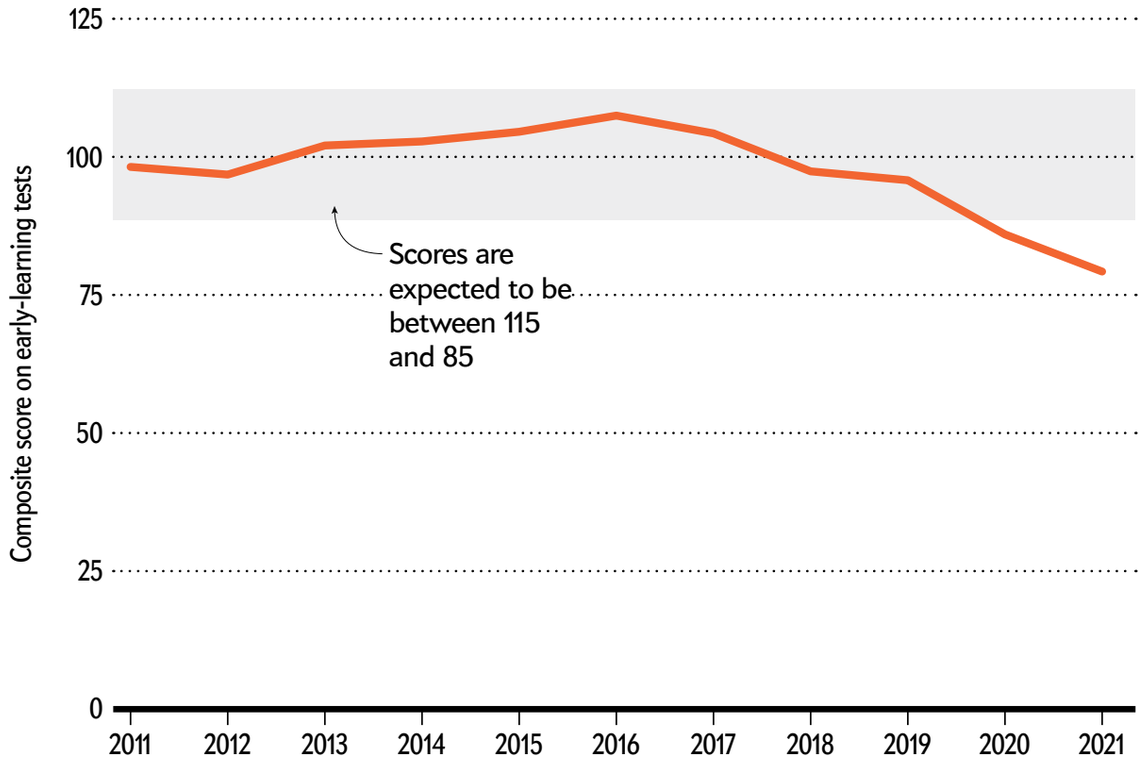
Other recent research supports the idea that lack of peer interactions could be holding some kids back. In a study published earlier this year, researchers in the United Kingdom surveyed 189 parents of children between the ages of 8 months and 3 years, asking whether their children received daycare or attended preschool during the pandemic, and assessing language and executive functioning skills. The authors found that the children's skills were stronger if they had received group care during the pandemic, and that these benefits were more pronounced among children from lower-income backgrounds.

Those most at risk seem to be children of color or those from low-income families. For instance, a growing body of research suggests that among school-aged children, remote learning might be widening the already large learning and development gaps between children from affluent and low-income backgrounds and between white kids and children of color. In the Netherlands, researchers found that youngsters did worse on national assessments in 2020—compared with the three previous years—and that learning losses were up to 60 percent larger for children from less educated families.

In parts of sub-Saharan Africa—including Ethiopia, Kenya, Liberia, Tanzania and Uganda—research sug-

Development Dip

Researchers tested the cognitive performance of more than 600 children aged 3 months to 3 years, including 39 babies born during the COVID-19 pandemic. On average, those assessed in 2020 and 2021 scored lower on tests of early learning, including language, puzzle-solving and motor skills such as standing and walking.



The COVID Generation: How Is the Pandemic Affecting Kids' Brains?," by Melinda Wenner Moyer, in *Nature*, Vol. 601; 2022

gests that some children have lost as much as a full year of learning. And in the U.S., after the first lockdown, a report by the consultancy firm McKinsey suggested that students of color began school in autumn three to five months behind in learning, whereas white students were only one to three months behind.

MASKED EFFECTS

Children who have attended school or other group settings during the pandemic have typically been interacting with others who wore face masks. One important question is whether masks, which obscure parts of the face that are important for expressing emotions and speech, might also be affecting kids' emotional and language development.

Edward Tronick, a psychologist at the University of Massachusetts Boston, has been bombarded with e-mails from parents and pediatricians concerned about the potential developmental effects of masking. Tronick is famous for his 1975 "Still Face" experiment, which showed that when birth parents suddenly remained straight-faced when interacting with their infants, their kids at first tried to get their attention and then slowly withdrew and grew increasingly upset and wary.

Tronick decided to see whether masks had a similar effect. With his colleague, psychologist Nancy Snidman, he conducted an experiment (which has not yet been peer-reviewed) in which parents used smartphones to record interactions with their babies before, during and after they put on face masks. Although babies noticed when their parents put on masks—they would briefly change their facial expression, look away or point at the mask—they would then continue interacting with their parents as they had before. The mask is blocking only one channel of communication, Tronick says: "The parent wearing a mask is still saying, 'I'm interacting with you, I'm still here for you, I'm still connecting to you.'"

"The parent wearing a mask is still saying, 'I'm interacting with you, I'm still here for you, I'm still connecting to you.'"

—Edward Tronick

Face masks don't seem to interfere all that much with emotional or language perception, either. A study published last May reported that two-year-olds were still able to understand words spoken by adults in opaque face masks. Children "compensate for information deficits more readily than we think," says study lead author Leher Singh, a psychologist at the National University of Singapore. Researchers in the U.S. found that, although face masks made it harder for school-age children to perceive adults' emotions—about as difficult as when adults were wearing sunglasses—the kids were still, for the most part, able to make accurate inferences.

"There's a lot of other cues that kids can use to parse apart how other people are feeling, like vocal expressions, body expressions, context," says study author Ashley Ruba, who is a postdoctoral fellow at the University of Wisconsin–Madison.

PREGNANT AND STRESSED

Other researchers are keen to know whether the pandemic could be affecting children's development before they are born. Catherine Lebel, a psychologist who runs the Developmental Neuroimaging Lab at the University of Calgary in Alberta, and her colleagues surveyed more than 8,000 pregnant people during the pandemic. Nearly half reported experiencing symptoms of anxiety, and one third had symptoms of depression—a much higher percentage than in prepandemic years. How was this stress affecting babies in the womb?

To find out, the researchers used MRI imaging to scan the brains of 75 of the babies three months after birth. In a preprint posted last October, they found that babies born to people who reported more prenatal distress—more anxiety or depression symptoms—showed different structural connections between their amygdala, a brain region involved in emotional processing, and their prefrontal cortex, an area responsible for executive functioning skills.

In a previous, small study, Lebel and her team had made the link between prenatal depression and brain connectivity differences in those same areas, and had suggested that in boys, these brain changes correlated with aggressive and hyperactive behavior at preschool age. Other teams have found that changes in connectivity between these areas in adults are risk factors for depression and anxiety. "Those are the areas that are involved in emotion processing, and lots of different behaviors," Lebel says.

Other research has found similar associations between prenatal pandemic stress and child development. Livio Provenzi, a psychologist at the IRCCS Mondino Foundation in Pavia, Italy, and his colleagues observed that three-month-old babies of people who reported experiencing more stress and anxiety during pregnancy had more problems regulating their emotions and attention—they were less able to maintain their attention on social stimuli, for instance, and were less easily soothed—than were babies of people who were less stressed and anxious during pregnancy.

Thomason is running her own study to assess the effects of maternal stressors on children's brains and behavior. She notes that, although there is a lot of concern about how prenatal stress might affect pandemic babies, early findings such as these do not mean that children are going to struggle for the rest of their lives. "Children are so adaptive and elastic. And we do expect that things are going to improve and that they should be able to be resilient to a lot of what's happened," she says.

Indeed, research on historical disasters suggests that, although stress in the womb can be harmful to babies, it doesn't always have lasting effects. Children born to people who experienced considerable stress as a result of the 2011 floods in Queensland, Australia, showed deficits in problem-solving and social skills at six months of age, compared with children born to people who experienced less stress. But by 30 months, these outcomes were no longer correlated with stress, and the more responsive that parents were to their babies' and toddlers' needs after birth, the better the toddlers did.

CAUTION AND ACTION

The research on pandemic babies presents a mixed picture, and scientists say it's too early to draw meaningful interpretations. For one thing, some of these early, often unpublished findings might not reflect reality, says Catherine Monk, a medical psychologist who works with Dimitriu at NewYork-Presbyterian.

The parents who chose to participate in some early studies, for instance, might not be a representative sample, Monk says. Perhaps they were already worried about their kids on the basis of the behaviors they are seeing. Furthermore, she says, the results of in-person studies such as Deoni's could be affected by the wearing of face masks—perhaps not a lot but enough to skew results.

As Thomason wrote last year in a commentary in *JAMA Pediatrics*, the incentive to publish interesting findings might also be shaping these early studies. "Scientists are quick to go look for a harmful difference. It's the thing that's going to get the attention of the media; it's the thing that's going to get published in a high-impact journal," she says.

"Scientists are quick to go look for a harmful difference. It's the thing that's going to get the attention of the media; it's the thing that's going to get published in a high-impact journal."

—Moriah Thomason

Researchers and funders are launching large studies and collaborations that could help to build a clearer picture. The U.S. National Institute on Drug Abuse is funding a handful of studies through its Healthy Brain and Child Development Study. These will look at how maternal stress and substance use during the pandemic affect child development. In addition, alliances and conferences have been formed to bring researchers together and share emerging data. In March 2020 Thomason launched the international COVID Generation Research Alliance, which brings together researchers from 14 countries studying families with young children during the pandemic. The alliance, which held a research summit in November 2021, includes researchers in North and South America, Europe, Australia, Asia, the Middle East and Africa.

Even if kids' brains are truly being affected by the pandemic, there is still time to steer them back on course, Dumitriu notes. "We can totally get ahead of this becoming a public health emergency," she says. "The brains of six-month-olds are very plastic, and we can get in there, and we can change their trajectory."

Parents can make headway by playing and talking with their young children regularly and giving them opportunities to play with others in safe settings. Policy changes aimed at supporting families and children could make a difference, too. Lebel's research found that meaningful social support, such as from a partner or close friend, during pregnancy resulted in much less prenatal distress. "We could do so much more of that in the prenatal care ecosystem," Monk says. Researchers also argue for interventions that support families immediately after birth. Provenzi's research has found that people who had just given birth and were visited at home by nurses and neonatologists experienced less stress and anxiety than those who did not receive these visits.

Overall, researchers maintain that most children will probably be okay—but more than usual might currently be struggling. And if we want to support those who are falling behind, we should ideally intervene soon. "Kids are certainly very resilient," Deoni says. "But at the same time, we also recognize the importance of the first 1,000 days of a child's life as being the crucial early foundations." The first pandemic babies, born in March 2020 are, at this point, more than 700 days old.

Children "are a product of their environment," Deoni says. "The more that we can stimulate them and play with them and read to them and love them—that's what it's going to take." **M**

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COVID Threatens to Bring a Wave of Hikikomori to America

We should work to protect others from falling into long-term social withdrawal

In 2014 a vibrant and well-traveled patient I will call Alice, whom I (Berman) was treating for bipolar disorder, began refusing to leave her home after a prolonged course of physical rehabilitation for a spinal injury. None of the usual diagnoses—depression, anxiety or agoraphobia—explained her withdrawal, which continued after medications stabilized her mood. Patients with these conditions typically maintain a desire to be with others, but Alice had shut out the world.

Recalling a 2010 paper by colleagues from the University of California, San Francisco, I suspected that Alice was experiencing hikikomori, a syndrome of extreme social isolation originally found in Japan that described primarily young men who confined themselves at home rather than attend school or go to work. The study proposed diagnostic criteria

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that have yet to be recognized in the U.S., expanding the definition of hikikomori to include any person who is homebound most of the day, nearly every day for over six months, as a result of persistent avoidance of social situations and relationships. After five years of psychotherapy, I got Alice to gradually venture out of her apartment until the COVID-19 pandemic siloed her back inside.

The tendency of some vaccinated people to continue self-isolating during periods of relatively low COVID infection rates has been called cave syndrome. Hikikomori is a chronic mental illness that stems from a fear of others, whereas cave syndrome is a temporary inability to readjust baseline social habits, such as not seeing friends or eating in restaurants. The danger comes when maladaptive behaviors are brushed off as cave syndrome when they are really the beginnings of hikikomori.

Hikikomori is a recent development in Western countries, with the bulk of epidemiological research on it having been conducted in Asian countries. A 2010 study estimates that 1.2 percent of Japan's population is experiencing hikikomori, and a 2015 survey finds a 2.6 percent prevalence of hikikomori in Hong Kong. Hikikomori was originally considered a culture-bound syndrome; however, a concerning number of case reports have been published in countries as diverse as Spain, South Korea and Nigeria. Two case reports of Americans with hikikomori have been reported in the past decade, and a survey conducted by researchers at the University of Buffalo found that 2.7 percent of a sample of U.S. university students have been affected by hikikomori in the past. Apart from these studies, there have been no systematic investigations into the prevalence of hikikomori in the U.S. Without this information, our health-care system is unequipped to help potentially thousands of homebound people who might have hikikomori. This includes people like Alice; homebound people are disproportionately older women of color.

The pandemic has made life very uncertain for people. In some ways, we are opening up, but in others, especially with the rise of COVID variants, we are talking about shutting down again.

American psychiatrists and researchers are largely unaware of hikikomori because it superficially resembles social anxiety disorder or agoraphobia; these were some of the illnesses I thought afflicted Alice until I dived a bit deeper. These disorders share social withdrawal as a symptom, but Alice's did not improve with medications. Furthermore, she denied having panic attacks, the hallmark of agoraphobia. I decided to focus on psychotherapy, which revealed that Alice's withdrawal was rooted in a fixed belief that she fundamentally could not belong in society, rather than just an anxiety about social situations.

Another obstacle to global acceptance of hikikomori is the incorrect assumption that, with a Japanese name, the condition is specific to Japan. There is also the larger issue of stigma against mental illness and homebound people, who are physically invisible to society and whose way of life has been normalized by the pandemic. Multiple barriers, namely, dependence on caregivers and difficulties with visiting primary care physicians, prevent homebound people from receiving adequate care. This limited access leads to excessive emergency room visits and hospitalizations, which is why homebound people account for roughly half of the most costly 5 percent of American patients.

To prevent people from progressing to hikikomori, we need to encourage family members or friends who are socially withdrawn and also experiencing symptoms of depression, anxiety or fatigue to leave their homes for exercise or meeting others face-to-face. In the situation where someone is consistently refusing care or denying the nature of their isolation, we recommend helping them seek a consultation with a psychiatrist or psychotherapist. Local community centers can facilitate social work and in-home health aide visits. And we recommend in-person visits; although telehealth appointments are convenient, they risk reinforcing self-isolating behaviors.

The pandemic has made life very uncertain for people. In some ways, we are opening up, but in others, especially with the rise of COVID variants, we are talking about shutting down again. While many of us look forward to returning to society when we feel it is safe to do so, some of us do not and will not. Throughout this next phase of our COVID lives, we must remember the invisible Americans like Alice who will have to fight a longer, more complicated battle to return to society.

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Why Kids Are Afraid to Ask for Help

Children as young as seven years old may hesitate to ask questions in school because they worry classmates will think they are "stupid"

JGI/Jamie Grill/Getty Images

Adults are often embarrassed about asking for help. It's an act that can make people feel vulnerable. The moment you ask for directions, after all, you reveal that you may be lost. Seeking someone's assistance can make you feel like you are broadcasting your incompetence.

New research suggests young children don't seek help in school, even when they need it, for the same reason. Until relatively recently, psychologists assumed that children did not start to care about their reputation and peers' perceptions until around age nine. But a wave of findings in the past few years has pushed back against that assumption. This research has revealed that children as young as age five care deeply about the way others think about them. In fact, kids sometimes go so far as to cheat at simple games to look smart.

Our research suggests that as early as age seven, children begin to connect asking for help with looking incompetent in front of others. Their concern about reputation may have significant consequences, particularly when it comes to education. At some point, every child struggles in the classroom. If they are afraid to ask for help because their classmates are watching, learning will suffer. With this knowledge, teachers and care-

givers should evaluate their practices and consider how they might make children more comfortable with seeking aid.

To learn more about how children think about reputation, we applied a classic technique from developmental psychology. Kids' reasoning about the world around them can be quite sophisticated, but they can't always explain what's going on in their mind. So we crafted simple stories and then asked children questions about these scenarios to allow kids to showcase their thinking.

Across several studies, we asked 576 children, ages four to nine, to predict the behavior of two kids in a story. One of the characters genuinely wanted to be smart, and the other merely wanted to *seem* smart to others. In one study, we told children that both kids did poorly on a test. We then asked which of these characters would be more likely to raise their hand in front of their class to ask the teacher for help.

The four-year-olds were equally likely to choose either of the two kids as the one who would seek help. But by age seven or eight, children thought that the kid who wanted to seem smart would be less likely to ask for assistance. And children's expectations were truly "reputational" in nature—they were specifically thinking about how the characters would act in front of peers. They could still conceive of situations in which the kid who wanted to seem smart would seek help: when assistance could be sought privately (on a computer rather than in person), children thought both characters were equally likely to ask for it.

We also asked kids about other scenarios. We found that they recognize several more behaviors that might make a child appear less smart in front of fellow kids, such as admitting to failure or modestly downplaying successes. Children are therefore acutely aware of several ways in which a person's actions might make them appear less astute in the eyes of others.

Given our findings, it seems quite possible that when children themselves are the ones struggling, they, too, might avoid seeking out help if they are concerned about reputation. If so, this reluctance to seek help when others are present could seriously impede academic progress. To improve in any domain, one must work hard, take on challenging tasks (even if those tasks might lead to struggle or failure) and ask questions. All of these efforts can be difficult when someone is concerned with their appearance to others.

How can we help children overcome these barriers? Our first instinct may be to motivate seeking help by emphasizing its educational benefits. But these efforts may not aid children whose primary concern is that they could appear incompetent. Research suggests that we may underestimate just how uncomfortable others feel when they ask for assistance.

Instead reputational barriers likely require reputation-based solutions. First, adults should lower the social stakes of seeking help. For instance, teachers could give children more opportunities to seek assistance privately by making themselves available to students for one-on-one conversations while classmates tackle group work. Teachers should couple this effort with steps that help students perceive asking questions in front of others as normal, positive behaviors. For example, instructors could create activities in which each student becomes an "expert" on a different topic, and then children must ask one another for help to master all of the material. If seeking help is understood as a commonplace classroom activity, kids may be less likely to think of it as indicative of one's ability.

Seeking help could even be framed as socially desirable. Parents could point out how a child's question kicked off a valuable conversation in which the whole family got to talk and learn together. After all, asking for help often benefits not just the help seeker but also others listening in who have similar questions or struggles. Moreover, adults could praise kids for seeking assistance. That response signals that they value a willingness to ask for help and not just effortless success.

Going forward, psychologists and educational researchers should evaluate these recommendations and develop new strategies that push young children past their fears about peer perceptions. There is one thing that they, as well as caregivers and teachers, need to keep clearly in mind: children think about their reputations, and try to manage them, more than we might assume.

Are you a scientist who specializes in neuroscience, cognitive science or psychology? And have you read a recent peer-reviewed paper that you would like to write about for Mind Matters? Please send suggestions to Scientific American*'s Mind Matters editor Daisy Yuhas at pitchmindmatters@gmail.com*

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Most of Us Combine Personality Traits from Different Genders

New research underscores that almost everyone's personality blends "more often seen in men" and "more often seen in women" characteristics

bashta/Getty Images

How different are men and women really? About 30 years ago, if dating guides are any indication, some people assumed vast differences in personality, with *Men Are from Mars, Women Are from Venus* relationship advice. Today, in contrast, certain communities are pushing back against the idea of binary gender, which presents men and women as separate categories. (A quick reminder: gender—described in terms such as "man," "woman" and "nonbinary person"—has strong cultural and social components, whereas sex—sometimes described with adjectives such as "male," "female" and "intersex"—refers to a combination of biological features.)

Scientists are also raising questions around gender, sex and personality. For one, researchers debate how big the personality differences between cisgender men and women truly are. The answer depends on how psychologists measure an individual's characteristics. For example, a study involving more than 300,000 people in the U.S., who self-identified as either male or female looked both at broad personality traits, such as extraversion and agreeableness, and more specific aspects of these traits, such as a warm communication style or tendency to act altruistically. In this sample, researchers found moderate differences between male and female participants in the broad traits but, in most cases, larger differences at the more specific level. Overall, for instance, both male and female individuals in the study were similarly extraverted (a broad trait). When the scientists looked at specific aspects of extraversion, however, they found that male participants, on average, sought out exciting situations more often than female ones did. And female participants demonstrated higher activity levels than male ones.

Researchers also argue about whether it makes more sense to study the size of personality differences by looking at one isolated characteristic at a time or by considering all traits simultaneously. The latter approach tends to produce substantially larger differences, much the way that male and female faces don't differ much if you look just at their eyes or nose but become easier to distinguish if you look at the whole face.

At ClearerThinking.org, a project that investigates the psychology of happiness and decision-making, we wanted to contribute to this discussion and help the public learn more about sex, gender and personality. We ran a series of 15 studies and conducted analyses on more than 15,000 people with the goal of testing the most comprehensive set of personality traits to date. Our analyses are limited to cisgender men and women because of our sample: 98 percent of our participants identified as either a "man" or "woman" and reported that this gender identity aligned with their sex assigned at birth. We therefore did not have enough data to shed light on the personality traits of nonbinary and transgender people—so although many individuals fall into these other categories, our research focused on cisgender men and women.

From the data, we discovered 18 specific self-reported traits that varied between these men and women. Next, we built an algorithm designed to predict a person's gender based on their self-reported scores on those traits, which was accurate 78 percent of the time. That accuracy is high but far from perfect, revealing the challenge of predicting an individual's gender from their combination of traits. Finally, we adapted our study questionnaire—in which people rated how much they agree with statements such as "I laugh aloud" and "I frequently worry"—into an online interactive assessment. You can try the quiz yourself to see how well the algorithm predicts your gender.

To create the questions for our studies, we cast a very wide net, looking at large personality projects, reviewing the academic literature and crowdsourcing ideas. We ended up testing more than 600 personality questions for gender differences before identifying the 18 traits with the greatest variation between the self-identified men and women in our sample. These traits included not only the broad characteristics that are widely used in psychological research (such as extraversion and agreeableness) but also more specific patterns of thought and behavior, such as how frequently an individual takes risks or their degree of focus on aesthetics. We also double-checked our conclusions by running a final study to replicate the major findings. Ultimately, we found no large differences in personality between cisgender men and women on any traits. But we did find small- and moderate-sized differences in the 18 personality traits.

The largest difference we detected was the degree to which cisgender people thought about sex, assessed by asking people to rate how much they agreed with the statement "I often have sexual thoughts when I meet an attractive-looking person" and disagreed with the statement "I do not frequently think about sex." (This "sex-focused" characteristic, while not linked to major personality traits commonly studied in psychology, nonetheless fits the conception of a personality trait as a pattern in thought, emotion or behavior. Furthermore, it relates to a concept called sexual preoccupation.) We found that gender could explain about 18 percent of the variation in the extent to which people are sex-focused. Men had a higher average score on this trait than women. There were still plenty of women who had a higher score than most men, however. In other words, individual men and women were highly varied, even though, at the group level, men tended to differ from wom-

en. We also found that, on average, men's self-reported personality was a bit more thick-skinned, risk-taking and self-valuing. In contrast, on average, women's self-reported personality was a bit more unselfish, compassionate and peaceful.

On every trait, there was a substantial overlap between men and women. Yet at the tail ends—where people either strongly agreed or disagreed with the questions we asked them—larger differences emerged. For example, very low compassion was rare in both men and women, but the few people who identified as very uncompassionate were much more likely to be men. This result is consistent with the finding that antisocial personality disorder, which often involves a lack of remorse or empathy, is more common among men than women.

So is there a "man's personality" and a "woman's personality"? Fascinatingly, almost everyone in our study was a mix of "more often seen in men" and "more often seen in women" traits. For any given trait, an individual woman was closer to the overall average for women than the overall average for men just 61 percent of the time. And a man was closer to the average for men than the average for women only 57 percent of the time. Only about 1 percent of men and 1 percent of women had almost entirely "more often seen in men" or "more often seen in women" personality traits. Accordingly, because nearly everyone is a mix of both, we named the personality assessment we had created from this research the Gender Continuum Test.

To test how accurately gender can be predicted from personality, we developed a simple machine-learning algorithm (a computer program that looked for patterns in data regarding which personality traits are associated with being a cis man or cis woman). We trained our algorithm using results from past study participants, then presented the algorithm with the personality traits of new participants to see how well it could predict their gender. Using just the most predictive trait—being sex-focused—the algorithm could predict a person's gender correctly 69 percent of the time. This result may be impressive to some. But the prediction is far from perfect because some women are much more sex-focused than the average man.

When the scientists looked at specific aspects of extraversion, however, they found that male participants, on average, sought out exciting situations more often than female ones did. And female participants demonstrated higher activity levels than male ones.

The algorithm's accuracy rose to 78 percent when we allowed it to incorporate all the personality differences at once. That's a big improvement—but for the other 22 percent of people, the algorithm was predicting incorrectly. When we released our quiz to the public, accuracy slipped a bit further to 74 percent. That's still much better than the average human, though: We gave another group of study participants sets of personality traits that, we explained, belonged to particular individuals. Then we asked the participants to predict the gender of those other people using the personality traits. They were correct only 58 percent of the time, hardly better than a coin flip.

We believe our results shed new light on the size of gender differences in personality. There are, however, some important caveats. First, all our study participants were from the U.S., and given that factors such as culture influence personality and gender, we would be hesitant to extend our conclusions to other communities. Second, our study cannot provide insight into the causes of personality differences—for instance, how much these differences can be explained by environment and culture as opposed to biology. Third, as noted, given our pool of participants, we don't have enough data to comment on transgender, intersex or nonbinary individuals. We hope future research explores these and other dimensions of the personality, sex and gender debate.

In the meantime, our study is a reminder that, on average, cisgender men and women do have some small to moderate differences in how they report their personality, but almost everyone is a mix of traits seen more often in men *and* seen more often in women. If you try to guess someone's personality from their gender, you'll very often be wrong.

Are you a scientist who specializes in neuroscience, cognitive science or psychology? And have you read a recent peer-reviewed paper that you would like to write about for Mind Matters? Please send suggestions to Scientific American*'s Mind Matters editor Daisy Yuhas at pitchmindmatters@gmail.com*

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The Devastating Loss of Grandparents among One Million COVID Dead

Grandparents are a majority of the pandemic's death toll

FG Trade/Getty Images

Think of the dead grandparents and everything they'll miss. All the milestones, the middle school graduations and bar mitzvahs and quinceañeras. All the victories, on soccer fields or piano recital halls. All the ordinary shared moments, dancing to *Baby Beluga,* or making banana bread, building extravagant Lego towers, watching *The Wizard of Oz* and cuddling at the flying monkeys part.

And the grandchildren, now bereft and sorrowful—think of everything they'll miss, too. The wide embrace, the rapt attentiveness, the patient re-reading of the same *Dory Fantasmagory* book over and over again. What those grandchildren have lost, two years into a ravaging pandemic that disproportionately kills the elderly, is a precious piece of their birthright: the feeling that they are totally and unconditionally adored, "gleaming with satisfaction at being this very child," as poet Galway Kinnell once put it. In Kinnell's poem, it was the parents who made the child feel so cherished, but to my mind, that glow is what grandparents provide best. Not even the most devoted parent has the time to marshal the unmitigated, unfiltered, focused adoration of a doting grandparent.

Scientists have known about the special balm of grandparents for a long time. In the 1980s the husband-and-wife team of Arthur and Carol Kornhaber looked at 300 grandparent-grandchild pairs in a longitudinal study. Arthur Kornhaber, a child psychiatrist, became interested in the subject after

treating a young patient named Billy, who had come to see him because of problems with attention, distractibility and dealing with frustration—symptoms that seemed to ease, Kornhaber learned, when Billy's grandmother was around. As part of therapy, Kornhaber asked the child to draw a picture of his family and describe what was happening. Billy drew a pyramid with himself on the top, running after a football. His parents were beneath him, "happy because I am a good football player." And at the bottom were his grandparents, also watching him play, "happy that I am happy."

That was it in a nutshell: the love Billy felt from his parents was a matter of earning their approval; the love from his grandparents was unconditional.

How many grandparent-sized holes have been created in families like Billy's today, as the U.S. faces the staggering one-million mark of deaths as a result of COVID? Based on that figure, a rough back-of-the-envelope calculation brings up an estimate of more than 614,000 lost grandparents because the great majority of those one million dead (74 percent) were age 65 or older, and the great majority of people in that age group (83 percent) have at least one grandchild.

Among that number were, possibly, some whose deaths brought a modicum of relief. Maybe their lives contained more suffering than joy; maybe infirmity or dementia had upended family dynamics. So let's set the staggering toll on the American family at about half a million active, involved, essential grandparents, give-or-take. Half a million elders who could have looked forward to years of acting as a family fulcrum, their presence now abruptly truncated and never to be replaced.

Today's grandparents help out in more modern ways. They support their children's careers by providing high-quality, loving (and generally free) child care; step in to raise their grandchildren when illness, drug abuse, divorce or a string of bad luck renders their adult children unable to cope; and mount political action to make the world better for the youngest generation.

The centrality of grandparents to family flourishing is nothing new. Throughout recorded history, involved grandparents, especially grandmothers, have helped promote the survival of their grandchildren, the stabilization of their communities, and even, according to the anthropological theory known as the grandmother hypothesis, the evolution of the species itself. While the very existence of postmenopausal women has been presented as an evolutionary mystery—Why would a species have evolved to spend up to one third of its typical life span unable to reproduce?—the grandmother hypothesis posits that they served an important adaptive role in our species' early history. Without the distraction of babies of their own, according to this theory, older women in hunter-gatherer societies could focus on the welfare of the youngest generation, providing food and guidance for those children while their daughters were occupied with their next babies.

The existence of grandmothers, especially maternal grandmothers, is thought to have helped early humans evolve a longer period of dependency during childhood, which in turn led to the development of a larger brain, a prolonged learning period and a more complex social life. And when having long-lived women in the family helped the youngest generation survive to reproductive age, Grandma was passing along her genes for longevity at the same time, thereby extending life expectancy overall.

Today's grandparents help out in more modern ways. They support their children's careers by providing high-quality, loving (and generally free) child care; step in to raise their grandchildren when illness, drug abuse, divorce or a string of bad luck renders their adult children unable to cope; and mount political action to make the world better for the youngest generation.

Grandparents' help with child care has a clear effect on young families: mothers of young children are up to 10 percent more likely to have paying jobs if a mother or mother-in-law lives nearby. Grandparents help out with finances more directly, too; 96 percent of American grandparents, according to AARP, give their adult children some form of financial assistance, most often for help with education (53 percent) or everyday living expenses (37 percent).

Helping out financially is especially common for

Black and Latino grandparents, who are more likely, on average, to help with their grandchildren's school expenses than the grandparent population as a whole (68 percent of Black grandparents and 58 percent of Latino grandparents do so). Grandparents of color are also disproportionately more likely to take on the role of full-time caregiver for their grandchildren—24 percent of "grandfamilies," where grandparents are raising their grandchildren, are Black, and 18 percent are Hispanic, even though Black and Hispanic individuals make up 10 and 8 percent, respectively, of the general population of adults older than age 50. Tragically Black and Hispanic grandparents are also significantly more likely than white grandparents to have died during the pandemic, with death rates from COVID that are roughly twice that of the general population—thereby, in the case of grandfamilies, making orphans of the children left to grieve.

In my own family, I like to think the help my husband and I have given our daughter and son-in-law has made the difference between managing and thriving as they raise their two little girls. COVID undid that benefit for a while. When the pandemic first hit, we—feeling especially vulnerable to COVID by virtue of being in our late 60s—were able to isolate in our privileged white cocoon. But it felt awful not to be able to help our daughter and son-in-law just when they most needed help—as they juggled full-time jobs with full-time day care for their girls, then aged almost two and almost five. It was agony to be reduced to pixels after having been a regular feature of the girls' lives—including Thursday day-care pickups, regular weekend visits, and three or four weeks spent together at the beach every summer.

Then a good friend from high school died after a stroke that might or might not have been related to COVID—this man, the same age as I was, died alone in a Manhattan hospital right down the street from me because his loved ones were kept from visiting—and the possibility of disappearing entirely from our granddaughters' lives became real. Every plan we'd ever made about future get-togethers with the grandkids seemed, on reflection, stupid and audacious. We could die from this.

So our Zooms with the girls, as imperfect as they were, suddenly felt precious—and felt like a way of helping out, in a way, as part of the homeschool routine our daughter cobbled together. Every morning at 9 A.M., my husband and I were responsible for remote "circle time." I tried not to notice how awkward it was to have a tea party through those infernal screens. I tried not to think about whether the girls felt abandoned or whether they wondered why we'd stopped showing up. I tried not to notice when the younger one started crying and calling our names as we clicked the "leave meeting" button.

We were lucky; we all got vaccinated as soon as we could, even our older granddaughter, and all the adults got boosted. The little one, now almost four, caught COVID during the Omicron wave, but she got through it with only a slight fever and didn't pass it to the rest of us.

A million people were not so lucky, and their grieving families are still dealing with the enormity of the loss.

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Cowboy Culture Doesn't Have a Monopoly on Innovation

Despite stereotypes that suggest self-reliant values lead to the most innovations, group-centered societies have just as much creativity

Chalisa Thammapatanakul/EyeEm/Getty Images

What does culture have to do with creativity? The answer could be "a lot." For decades, psychologists trying to understand the roots of creative imaginations have looked at the way two kinds of cultures affect artistic and inventive efforts. Individualistic (sometimes called "cowboy") cultures encourage people to be unique and to prioritize their own interests, even if doing so costs the group overall. Collectivistic cultures are based on relationships and duties to other people, often sacrificing the individual's wants for the needs of close others or the community.

Individualism has long been thought to have a creative edge. Individualists resist social convention, the logic goes, and that pushback supports innovation. For instance, around the world, individ-

ualistic cultures have more invention patents than collectivistic cultures do. That advantage remains even when we compare only countries with similar wealth—an important control because affluent countries hold more patents on average.

But a new study suggests that these ideas about culture and creativity could be off base. People in collectivistic cultures actually do better with a particular type of creative thinking than people in individualistic cultures. This creativity could be linked to what their ancestors farmed—and the findings overall reveal the shortcomings of thinking about innovation too narrowly.

The new work comes from comparing communities in different parts of China. Although it scores high, as a nation, on measures of cultural collectivism, China's 1.4 billion people are more than just a single culture. As my own work has explored, there are distinct individualistic and collectivistic communities within China. For example, psychological tests conducted by my colleagues and me suggest that people from areas north of the Yangtze River tend to be more individualistic, open to strangers and assertive, whereas people along the river and farther south are often more interdependent, partial to friends over strangers and likely to try to fit in without being disruptive.

In the new creativity study, researchers in Hong Kong investigated innovation with these two groups in mind. Although creativity is notoriously hard to measure, they used a drawing test created by psychologists. The team gave kids a sheet of paper with just a few basic elements printed on it: some dots here, squiggles there and a rectangle that suggested a drawing frame. The children got 15 minutes to draw what they wanted. They received no specific instructions beyond using the elements already on the page in some way.

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What was notable about the test was that it had a formal scoring system to measure different kinds of innovative thinking in each participant's artwork. For instance, the children could get "adaptive creativity" points for doodling in ways that connected the squiggles and lines into an original but unified image. In addition, a judge checked whether the children chose to incorporate a small shape just outside what looked like a rectangular drawing frame. That element was easy to miss and could have been misconstrued as a printing error, but kids that included this outside-the-box detail could get points for "boundary-breaking creativity."

The researchers in China gave the test to 683 middle school students from north and south of the Yangtze River. Then they gave the drawings and scoring rubric to the judge, who had no other information about the study. When the scientists got the scores back, they discovered there were no differences in the children's overall creativity. In other words, kids from individualistic communities did not have an edge in this task. When broken down into components, in fact, students from collectivistic regions scored higher in adaptive creativity. The middle schoolers from individualistic areas scored higher in boundary-breaking creativity.

As silly as the drawing task might sound, past studies have found that what people draw correlates with what they do outside the lab. Students who score high on this test—regardless of the type of creativity they demonstrate—also tend to write stories that independent judges deem more creative. And kids who score high in boundary-breaking creativity take more creative pictures and score higher on personality measures of openness.

More broadly, research with adults suggests that boundary-breaking creativity supports innovations that revolutionize or shake up a field. In line with that idea, the kids who scored high in boundary breaking live in parts of northern, more individualistic China, which has more patents for inventions. In contrast, adaptive creativity comes into play when people improve existing technologies and approaches, developing "next generation" solutions that build on what has been done to date. This difference might explain why much of China's manufacturing sector, which has grown through incremental improvements in processes and technologies, has sprung up in the southern, collectivist areas—the same regions where kids with higher adaptive creativity scores were raised.

This new study also suggests that a culture's

deep history matters. Just as some scholars have connected individualism in the U.S. and elsewhere to cowboys, my research explores how today's collectivistic and individualistic cultures in China may reflect the agricultural heritage of specific regions. Along the Yangtze River and farther south, people have farmed paddy rice for generations. To the north, they have farmed wheat.

Rice farming is a lot more work than wheat farming. Anthropologists observing traditional agriculture in China, Malaysia and West Africa have found that rice farmers spent about twice as many hours working their fields as wheat farmers. That difference led rice farmers to create labor-exchange systems: "You help me this week; I'll help you next week." (Of course, rice villages didn't invent the idea of helping one another—my ancestors in Kansas's corn fields went to communal barn raisings—but research suggests that labor exchanges were a more critical, binding part of relationships in rice villages than in other farming regions.) In addition, while wheat farmers could rely on rainfall, paddy rice farmers needed to build irrigation systems to get enough water. Shared irrigation required rice farmers to work together, sometimes filling and draining fields in sync and splitting the system's maintenance tasks.

The upshot is that rice and wheat farming put southern and northern China on different cultural paths with enduring consequences. It's safe to say that few (if any) of the middle school students in the creativity study have farmed rice or wheat themselves. Yet what many of them drew when pen hit paper connects to their ancestors' agricultural legacy. Culture has roots that are sometimes hidden even from the people it touches.

The findings are also a warning against cultural chauvinism. If we zoom out, the differences between China's individualistic north and collectivistic south might offer a microcosm for ideas that people have held about the "collectivistic East and individualistic West" writ large. Western countries have tended to lead the way in innovation—at least as defined by the metrics we Westerners have created. Perhaps we have been overlooking China's prowess at adaptive creativity. For example, China didn't invent the assembly line, but the nation's people improved this system in what has become a flourishing manufacturing sector.

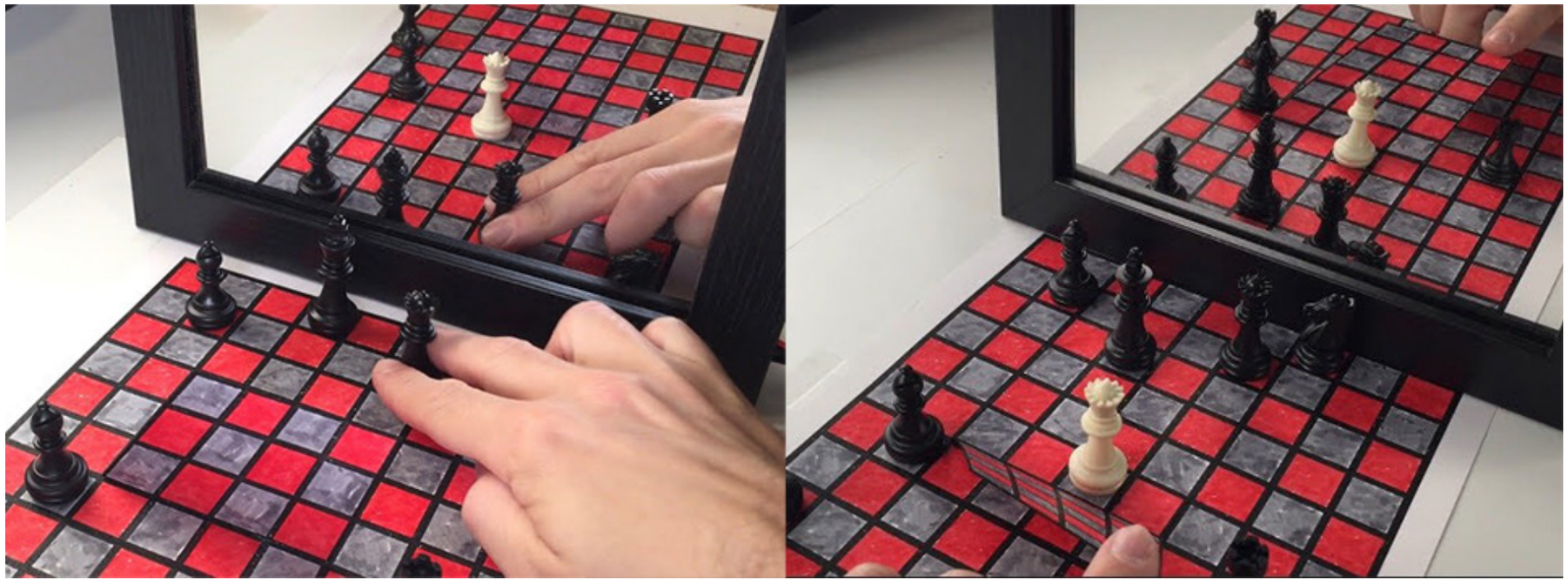
The scientists behind the drawing test conclude that adaptive and boundary-breaking creativity are two different and useful skill sets. Their results with students in the rice and wheat regions support prior research that has asserted that individualists break boundaries because they are more "open to new experiences, autonomous, self-confident, and impulsive," whereas collectivists may be better at connecting ideas and adapting them in the implementation stage, the researchers write. The true takeaway might be in recognizing the power of pairing these approaches: a little rice and a little wheat.

Are you a scientist who specializes in neuroscience, cognitive science or psychology? And have you read a recent peer-reviewed paper that you would like to write about for Mind Matters? Please send suggestions to Scientific American*'s Mind Matters editor Daisy Yuhas at pitchmindmatters@gmail.com*

Susana Martinez-Conde and **Stephen Macknik** 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.*

The Phantom Queen

Her majesty's invisibility cloak is a matter of perspective



The Phantom Queen Illusion is shown at the left. At the right, a behind-the-scenes look reveals the anamorphic camouflage causing the effect.

Matt Pritchard

Black chess pieces move across a hand-drawn red-and-gray chessboard. A black-framed mirror, placed in front of the board, reflects the progress of rooks and bishops across the space. Except that something is not quite right. The white queen, standing at the center of the board, exists only in the mirror reflection. In the foreground, the physical board's central squares appear incongruously empty. The Phantom Queen Illusion, conceived by U.K. magician Matt Pritchard, astonished worldwide viewers last December, winning first prize in the 2021 Best Illusion of the Year Contest.

Although Pritchard's queen appears simultaneously present and absent, this is neither a quantum paradox nor image manipulation. The answer lies in Pritchard's clever use of anamorphic camouflage, combined with dual—and seemingly incompatible—perspectives. Anamorphic perspective is a type of distorted projection that relies on the viewer assuming a specific vantage point. In Pritchard's illusion, the critical component is a camouflaged "invisibility cloak," whose shape and pattern shield the queen from not just one but two viewing angles: the viewer's vantage point and the mirror's reflection.

Pritchard devised the deception after reading a book of photography tricks by Walter Wick. "One picture featured an 'invisible cube' that was painted to blend in with the background," he recalls. "The magician within me started to wonder how I could exploit an invisible object in a scene. I decided to use it as an [undetectable] shield to hide an extra object before making it appear."

Next, Pritchard asked himself if he could make a shield that would work from two angles. "After many dozens of attempts, I managed to design a shape and pattern that could work from both sides.... Since I was using a checker pattern, a chessboard-themed illusion was a natural choice." To complete the effect, Pritchard optimized the lighting to remove any telltale shadows from the image.

The last factor in the deceit was the viewer's own mind and its faulty assumptions. "We've become accustomed to looking at a reflection and seeing a reversed image of a scene," Prichard says. "It's disarming to find a major discrepancy between the real and the virtual images."

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