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Psychology reveals that in some circumstances it's better to be a bit mindless

WITH COVERAGE FROM nature

Liz Tormes

A Wandering Mind

In 2017 *Scientific American* published an important article by Stanford University professor of medicine Marcia L. Stefanick that detailed all the ways modern medicine has failed women—namely, by basing their care on research findings gathered predominately on men and men alone. To be sure, improvements have been made to treating women in cardiovascular health, mental health care and prescription dosing, but much research on women's health is still in early days. In this issue, journalist Katharine Sanderson covers the latest example of this discrepancy: head injury (see "Why Sports Concussions Are Worse for Women"). There's no denying now that equality in medical research would be a great way to start leveling the playing field.

Our cover story this month explores the intriguing effects that automaticity—that is, mindless activity—can have on mental and physical performance (see "Sometimes Mindlessness Is Better Than Mindfulness"). As environmental anthropologist Peter Sutoris writes in Opinion, our hyperconsumeristic culture prizes productivity above all else (see "To Solve the Environmental Crisis, We Must Foster the Power to Imagine"). It may be that easing up on our relentless concentration and letting the mind wander may have benefits that go beyond an individual's scope.

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On the Cover

Psychology reveals that in some circumstances it's better to be a bit mindless

WHAT'S INSIDE

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NEWS

Making Eye Contact Signals a New Turn in a Conversation

Neuroscientists have uncovered an intriguing subtlety in how we communicate—that is, when we're not on Zoom

What is found in a good conversation? It is certainly correct to say words—the more engagingly put, the better. But conversation also includes "eyes, smiles, the silences between the words," as the Swedish author Annika Thor wrote. It is when those elements hum along together that we feel most deeply engaged with, and most connected to, our conversational partner, as if we are in sync with the person.

Like good conversationalists, neuroscientists at Dartmouth College have taken that idea and carried it to new places. As part of a series of studies on how two minds meet in real life, they reported surprising findings on the interplay of eye contact and the synchronization of neural activity between two people during conversation. In a paper published on September 14 in the *Proceedings of the Natural Academy of Sciences USA,* the researchers suggest that being in tune with a conversational partner is good but that going in and out of alignment with them might be better.

Making eye contact has long been conceived as acting like a cohesive glue, connecting an individual to the person with whom he or she is talking. Its absence can signal social dysfunction. Similarly, the growing study of neural synchrony has focused on the positive aspects of alignment in brain activity between individuals.

In the new study, by using pupil dilation as a measure of synchrony during unstructured conversation, psychologist Thalia Wheatley and graduate student Sophie Wohltjen found that the moment of making eye contact marks a peak in shared attention—and not the beginning of a sustained period of locked gazes. Synchrony, in fact, drops sharply after looking into the eyes of your interlocutor and only begins to

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recover when you and that person look away from each other. "Eye contact is not eliciting synchrony; it's disrupting it," says Wheatley, senior author of the paper.

Why would this be? Conversation requires some level of synchrony, but Wheatley and lead study author Wohltjen speculate that breaking eye contact ultimately propels the conversation forward. "Perhaps what this is doing is allowing us to break synchrony and move back into our own heads so that we can bring forth new and individual contributions to keep the conversation going," Wohltjen says.

"It's a fantastic study," says psychiatrist and social neuroscientist Leonhard Schilbach of the Max Planck Institute of Psychiatry in Munich, who studies social interaction but was not involved in the research. He applauds the design of the experiment to replicate natural encounters and the focus on free-form conversation. The results suggest, he says, that "interpersonal synchrony is an important aspect of social interactions but may not always be desirable."

Others in the field are drawn to the researchers' creative way of thinking about conversation, which is described as "a platform where minds meet" in the paper. "Such a conceptualization may inspire other researchers to think about conversation differently and study it more deeply," says Juliana Schroeder, a social psychologist at the Haas School of Business at the University of California, Berkeley, who also was not involved in the research.

The new work builds on an earlier study by Wheatley and psychologist Olivia Kang, now at Harvard University, who showed that pupillary synchrony serves as a measure of shared attention. Our pupils get larger and smaller as a reflexive response to changes in light but also, to a lesser degree, when we are physiologically aroused. Kang and Wheatley tracked eye movements in speakers as they recounted positive or negative memories about their life. Then the researchers tracked the eye movements of people listening to the same stories at a later point in time. They found that the pupil dilation of the listeners synchronized to that of the speakers when there were emotional peaks in the stories. "We knew this was a marker of people being on the same page as each other," Wheatley says.

For the current paper, Wohltjen wanted to extend those earlier findings by studying face-to-face conversation in order to see how eye contact might influence shared attention in real time. She put 186 psychology students at Dartmouth, all relative strangers, into conversational pairs and asked them to talk for 10 minutes about anything they wanted while she tracked their eye movements. Participants also watched videos of their conversations and rated their remembered level of engagement minute by minute.

"We expected that eye contact worked like a cattle prod to get two people back onto the same wavelength," Wohltjen says. If that were so, the onset of eye contact should have led to a subsequent increase in pupillary synchrony. Instead the researchers found the opposite: a peak in synchrony at the onset followed by a decrease. But they also found that participants reported being more engaged when they were making eye contact. "We thought, 'Perhaps this making and breaking of eye contact must do something to help the conversation,'" Wohltjen says.

Previous studies of eye contact have generally been passive, as in Wheatley and Kang's earlier work. The real-world design of Wohltjen's experiment served as a reminder that most people naturally look at and away from each other many times during a conversation. Holding someone's gaze for too long—or not at all—can seem awkward. As the researchers thought further about what eye contact might be doing for us, they turned to the literature on creativity. There they recognized the constraints of too much synchrony. "If people are trying to innovate in some way, you don't want people in lockstep with each other," Wheatley says. "You want people to [say], 'What if we did this? What if we did that?' You need people to be providing their independent insights and building that way."

The idea that eye gaze can be used to modulate synchrony is intriguing to other researchers. "The elegant experimental approach [in this paper] might be helpful to quantitatively investigate psychiatric conditions, which can be described as 'disorders of social interaction,'" says Schilbach, who has studied gaze and other elements

of social interaction in autism.

The findings also help explain the frustrations of Zoom and other video conferencing platforms, on which real eye contact is nearly impossible to make—or break—because of the positioning of cameras and windows on screens. (The paper's publication prompted a lively discussion of just that phenomenon on Twitter.)

Wheatley can imagine follow-up studies that examine a variety of conversational contexts. How does the dynamic dance between making and breaking synchrony play out when a parent is instructing a child, for instance? Presumably, in that situation, a parent would be hoping for the child's full attention and therefore complete synchrony. On the other hand, perhaps the study helps explain why long car rides, in which people do not look at each other the whole time, are often conducive to deep conversation.

"There might be an optimal sweet spot in this coupling, decoupling thing—where people are really listening to each other, but they're also fueling the conversation with new ideas," Wheatley says. "Those conversations might be the most fun."

—Lydia Denworth

Misophonia Might Not Be about Hating Sounds After All

The phenomenon triggers strong negative reactions to everyday sounds but might come from subconscious mirroring behavior

To a chef, the sounds of lip smacking, slurping and swallowing are the highest form of flattery. But to someone with a certain type of misophonia, these same sounds can be torturous. Brain scans are now helping scientists start to understand why.

People with misophonia experience strong discomfort, annoyance or disgust when they hear particular triggers. These can include chewing, swallowing, slurping, throat clearing, coughing and even audible breathing. Researchers previously thought this reaction might be caused by the brain overactively processing certain sounds. Now, however, a new study published in the *Journal of Neuroscience* has linked some forms of misophonia to heightened "mirroring" behavior in the brain: those affected feel distress while their brains act as if they are mimicking the triggering mouth movements.

Some cannot stand the sound of others eating.

Catherine Falls *Getty Images*

"This is the first breakthrough in misophonia research in 25 years," says psychologist Jennifer J. Brout, who directs the International Misophonia Research Network and was not involved in the new study.

The research team, led by Newcastle University neuroscientist Sukhbinder Kumar, analyzed brain activity in people with and without misophonia when they were at rest and while they listened to sounds. These included misophonia triggers (such as chewing), generally unpleasant sounds (like a crying baby), and neutral sounds. The brain's auditory cortex, which processes sound, reacted similarly in subjects with and without misophonia. But in both the resting state and listening trials, people with misophonia showed stronger connections between the auditory cortex and brain regions that control movements of the face, mouth and

throat. Kumar found this connection became most active in participants with misophonia when they heard triggers specific to the condition.

"Just by listening to the sound, they activate the motor cortex more strongly. So in a way it was as if they were doing the action themselves," Kumar says. Some mirroring is typical in most humans when witnessing others' actions; the researchers do not yet know why an excessive mirroring response might cause such a negative reaction, and they hope to address that in future research. "Possibilities include a sense of loss of control, invasion of personal space, or interference with current goals and actions," the study authors write.

Fatima Husain, a University of Illinois professor of speech and hearing science, who was not involved in the study, says potential misophonia therapies could build on the new findings by counseling patients about handling unconscious motor responses to triggering sounds—not just coping with the sounds themselves. If this works, she adds, one should expect to see reduced connected activity between the auditory and motor cortices.
—Christiane Gelitz and Maddie Bender

A New Way to Understand—and Possibly Treat—OCD

People with the disorder seem to have a more flexible "sense of self"

Obsessive-compulsive disorder (OCD) has puzzled artists and scientists for centuries. Afflicting one in 50 people, OCD can take several forms, such as compulsively putting things in just the right order or checking if the stove is turned off 10 times in a row. One type of OCD that affects nearly half of those with the condition entails irresistible washing urges. People with this type can spend hours scrubbing their hands in agitation after touching something as trivial as a doorknob even though they know this makes no sense. There is currently a shortage of effective therapies for OCD: 40 percent of patients do not benefit from existing treatments.

A major issue is that today's treatments are often too stressful. First-line "nonpharmacological therapies" involve telling patients to repeatedly touch things such as

Os Tartarouchos *Getty Images*

toilet seats and then refrain from washing their hands. But recent work by my colleagues and me has found something surprising: people diagnosed with OCD appear to have a more malleable "sense of self," or brain-based "self-representation" or "body image"—the feeling of being anchored here and now in one's body—than those without the disorder. This finding suggests new ways to treat OCD and perhaps unexpected insights into how our brain creates a distinction between "self" and "other."

In our recent experiments, for example, we showed that people with and without OCD responded differently to a well-known illusion. In our first study, a person without OCD watched as an experimenter used a paintbrush to stroke a rubber hand and the subject's hidden real hand in precise synchrony. This induces the so-called rubber hand illusion: the feeling that a fake hand is your hand. When the experimenter stroked the rubber hand and the real one out of sync, the effect was not induced (or was greatly diminished). This com-

pelling illusion illustrates how your brain creates your body image based on statistical correlations. It's extremely unlikely for such stroking to be seen on a rubber hand and simultaneously felt on a hidden real one by chance. So your brain concludes, however illogically, that the rubber hand is part of your body.

After a few minutes of such stroking, we "contaminated" the fake hand (using items such as fake feces). Intriguingly, participants without OCD reported feeling OCD-like disgust, which seemingly arose from the rubber hand. This experiment was later replicated in a large study in Japan, indicating that the finding is robust across cultures. Put differently, beyond feeling like the rubber hand was their own (the standard illusion), the subjects were disgusted by what it was touching.

In a follow-up study my colleague Vilayanur S. Ramachandran of the University of California, San Diego, and I—along with Richard J. McNally, Jason A. Elias and Sriramya Potluri, all then at Harvard University—found that people with OCD felt like the fake hand was theirs even when the experimenter stroked the real and rubber hands out of sync with each other. As noted, the illusion occurs because your brain extracts statistical correlations from sensory inputs: you feel your unseen hand being stroked and see the fake hand being touched the exact same way. The fact that people with OCD experienced a vivid illusion during out of sync stroking suggests they have a more expansive self-representation to the degree that they are willing to seamlessly ignore conflicting sensory inputs—and still accept the rubber hand as their own. Indeed, this is the first study to suggest that OCD involves a more malleable body image; in other words, it is the first to indicate that people with the condition construct their sense of self differently than others. Just as in our previous study, inducing the rubber hand illusion and smearing the rubber hand with fake feces provoked disgust—apparently fooling the brain into attributing the disgust to the fake hand.

Taken together, these studies indicate that the "self" is more fluid for people with OCD. Their greater susceptibility to the rubber hand illusion might be explained by dysregulation of chemicals such as dopamine (a feature of OCD). The studies also suggest that once the rubber hand trick is induced, contaminating the fake hand might activate brain modules involved in disgust. The experiments illustrate how seemingly unrelated brain centers—for vision, touch and disgust—may interact in a dynamic fashion to weave together perceptual reality. Indeed, just the right kind of physical stimulation for a few minutes can make someone abandon a lifetime of experience that a rubber hand is not a part of their body. Astonishingly, when presented with this scenario, you will make the perceptual decision that a fake hand is yours and experience bona fide contamination sensations arising from it.

There is currently a shortage of effective therapies for OCD: 40 percent of patients do not benefit from existing treatments.

In a related study, Ramachandran and I found that college students with OCD symptoms felt disgust while watching an experimenter contaminate himself and relief while watching him wash his hands—suggesting that highly visceral disgust reactions, as experienced in the context of OCD-like contamination aversion, can ultimately break down the barrier between self and other. Surprisingly, we found that to people with OCD symptoms, it didn't matter whether they or the experimenter was contaminated—they felt equally disgusted! Participants' verbal reports about how disgusted they felt were the same both when they touched the contaminant and when they merely watched the experimenter do so.

Even more intriguingly, once the participants had contaminated themselves, they reported relief from watching the experimenter washing his own hands. Notably, some participants would dictate how the experimenter should wash his hands, saying things such as "Wash more on this side" or "Pour more water between these fingers." Echoing these results, we recently found that OCD patients at McLean Hospital in Massachusetts reported experiencing handwashing urges arising from watching an experimenter contaminate himself. They also reported

feeling equally disgusted and anxious both when watching an experimenter contaminate himself and when they themselves were contaminated.

Finally, once the patients had contaminated themselves, they reported feeling relief—reductions in disgust by 22 percent, equivalent to actual handwashing—from watching the experimenter washing his own hands. Overall, these results are counterintuitive. They demonstrate the elusive interface between mind and body and feelings such as disgust. It may be that contamination feelings in OCD have the potential to override logic and the "self-other" barrier.

Our studies may lead to new treatments for OCD. Traditional therapy has patients touch disgusting things, then shows them that nothing bad happens when they don't wash their hands. These treatments don't always work well, because patients are too anxious to touch contaminated objects. But what if a rubber hand that feels like the patient's own is contaminated instead? Indeed, such prolonged contamination of a fake hand should eventually lead to desensitization just like traditional therapy. Unlike standard OCD treatment, this novel rubber hand therapy—which we've dubbed "multisensory stimulation therapy"—does not require patients to touch highly aversive "contaminants." Accordingly, patients who are too frightened to engage in traditional therapy because of the direct skin exposure may be more willing accept this technique.

Likewise the observations that feelings of contamination and relief can arise vicariously may pave the way for new treatments. Watching a video of oneself touching disgusting objects should have a desensitizing effect over time. Similarly, patients could repeatedly watch themselves washing their hands to eradicate washing urges. With our colleagues, Barbara J. Sahakian of the University of Cambridge and I found that people with contamination fears improved their OCD symptoms by simply watching a brief video of themselves touching fake feces or washing their hands on a smartphone a few times daily for a week. OCD is a perplexing condition that blurs the boundary between mind and body, reality and illusion. One may have to fool the brain to overcome the condition—combating one illusion with another.

—Baland Jalal

High-Profile Autism Genetics Project Paused amid Backlash

Study aimed at collecting DNA from 10,000 autistic people and their families has drawn criticism for failing to consult the autism community

A large U.K.-based study of genetics and autism spectrum disorder (ASD) has been suspended, following criticism that it failed to properly consult the autism community about the goals of the research. Concerns about the study include fears that its data could potentially be misused by other researchers seeking to "cure" or eradicate ASD.

The Spectrum 10K study is led by Simon Baron-Cohen, director of the Autism Research Center (ARC) at the University of Cambridge. The $4-million project, which is funded by the London-based biomedical funding charity Wellcome, is the largest genetic study of ASD in the U.K. It aims to collect DNA samples, together with information on participants' mental and physical health, from 10,000 autistic people and their families. This will be used to study the genetic and environmental contributions to ASD and to co-occurring conditions such as epilepsy and gut-health problems. "If we can understand why these co-occurring conditions are more frequent in autistic people, that could open the door to treatment or management of very distressing symptoms," Baron-Cohen says.

But soon after the study's high-profile launch on August 24, autistic people and some ASD researchers expressed concern that it had gone ahead without meaningfully consulting the autism community. Fears about the sharing of genetic data and an alleged failure to properly explain the benefits of the research have been raised by a group called Boycott Spectrum 10K, which is led by autistic people. The group planned to protest outside the ARC premises in Cambridge in October. A separate petition against the study gathered more than 5,000 signatures.

Damian Milton, a researcher in intellectual and developmental disabilities at the University of Kent, is one of those who signed the

Boycott Spectrum 10K petition. Milton has been diagnosed with Asperger's syndrome, a form of ASD. He says it is not clear how the study will improve participants' well-being, and its "aim seems to be more about collecting DNA samples and data sharing."

As a result of the backlash, the Spectrum 10K team paused the study on September 10, apologized for causing distress, and promised a deeper consultation with autistic people and their families.

The Spectrum 10K study aims to collect DNA from 10,000 autistic people and their families.

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SCREENING FEARS

Even before Spectrum 10K launched, some autistic people were uncomfortable with aspects of Baron-Cohen's research. He developed and popularized the controversial extreme male brain theory of ASD, which is based on the idea that, on average, males are better than females at systematizing—recognizing patterns and sticking to rules—whereas females are better at empathizing. Behavior seen in autistic people, Baron-Cohen asserts, sits firmly at the male end of this continuum.

"I think Simon has made some really prominent contributions to autism theory," says Sue Fletcher-Watson, a psychologist at the University of Edinburgh, who studies ASD. But "there's a component of suggesting that autistic people don't have empathy," she says. "That has been extremely damaging and stigmatizing for autistic people and is very much at odds with many autistic people's lived experience, which is often a sort of uncontrollable excess of empathy."

The antipathy toward these theories is now overlaid by concerns about the genetic research planned by Spectrum 10K and how the study will share its data. Many funding bodies, including Wellcome, mandate researchers to make their results freely available. But critics of Spectrum 10K want assurances that the genetic data will not be misused by researchers, and fear that the open-access policy means the project cannot

"That has been extremely damaging and stigmatizing for autistic people and is very much at odds with many autistic people's lived experience, which is often a sort of uncontrollable excess of empathy."

—Sue Fletcher-Watson

guarantee against this possibility.

Kieran Rose, an advocate for autistic people and a member of the Boycott Spectrum 10K group, says he is worried that the research could lead to a prenatal screening test for ASD or related conditions. "A genetic study would be terrifying for lots of autistic people; there's a long-established and well-known history around eugenics and disability," adds Fletcher-Watson.

The Spectrum 10K Web site states that it "does not aim to eradicate autism." Baron-Cohen says that his team is vehemently against eugenics and that prenatal screening is out of the question. "Genetics of autism is complex; we may be talking about hundreds or thousands of genes," he says. "You could never diagnose autism prenatally, and that's because, even if we knew the biology, diagnosis rests on behavior. That's only possible to observe postnatally."

CONSULTATION CONTROVERSY

The autism community is also frustrated that it was not consulted by Spectrum 10K about the kind of research that would best serve autistic people. Autistica, a London-based ASD charity, initially lent its support to the study but subsequently asked the Spectrum 10K team to remove its endorsement from study material. "There is a real need for a broader discussion between autistic people and their families and researchers," says James Cusack, Autistica's chief executive.

To address these misgivings, the Spectrum 10K team is now planning a consultation with hundreds of autistic people and their families and intends to create a representative committee to oversee the project's data-sharing strategy. "If there are ethical reasons for limiting who can access the data, that's fine, you can put those constraints in place," Baron-Cohen says.

In a statement, a Wellcome spokesperson said: "We are fully supportive of the researchers' plans to pause and undertake further engagement work, consistent with inclusive research principles."

The pause could last several months. Meanwhile the Health Research Authority (HRA), a U.K. regulator of health- and social-care research, is investigating several unspecified concerns about Spectrum 10K's ethics approval. That investigation might take several weeks, and Spectrum 10K cannot restart without the HRA's permission, says Eve Hart, the HRA's head of communications.

"I do think a research team with this level of experience in autism research should have seen this coming," Fletcher-Watson says. "They should have done more groundwork to engage with the community and prevent the distress that's been caused, and to design a study that would serve the community's needs."

—Katharine Sanderson

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Navigating a Virtual World Helped Older Adults' Memory

A virtual-reality game may boost one long-term memory measure

Scientists have long sought to prevent sharp memories from dulling with age, but the problem remains stubborn. Now research published in *Scientific Reports* suggests virtual reality might help older people recall facts and events based on specific details.

The study involved 42 healthy older adults from the San Francisco Bay Area. Half spent a dozen hours over four weeks playing a virtual-reality game called Labyrinth; they strapped on headsets and walked in place, roaming virtual neighborhoods while completing errands. The other half, in the control group, used electronic tablets to play games that did not require navigating or recalling details. After 15 sessions, the latter performed roughly the same as before on a long-term memory test based on picking out objects they had seen about an hour earlier. But

Getty Images

the Labyrinth players' scores rose, and they were less frequently tricked by objects that resembled ones they had viewed.

Those improvements "brought them back up to the level of another group of younger adults who did the same memory tests," says cognitive neuroscientist Peter Wais of the University of California, San Francisco. He and his colleagues designed the VR game, which they say likely stimulates the hippocampus—a brain area important for long-term memory. The team did not observe improvement on two other tests, which measured autobiographical memory and spatial memory capability.

"What they're trying to do is uniquely suited to VR," says Meredith Thompson, a Massachusetts Institute of Technology education researcher, who studies learning through VR games but was not involved in the new study. VR can provide greater immersion and engagement than other games, she says, adding that after this proof-of-concept study, "it would be great to actually follow people over time and see what this type of game does for long-term memory."

Wais's team is now investigating how long the observed effects last and which elements of the training have the most impact.

"It's great that they measured expectations for improvement for the intervention and placebo conditions," says Daniel Simons, a University of Illinois at Urbana-Champaign cognitive psychologist, who was also not involved in the study. Experiments with other games that claim to train the brain have often failed to evaluate this, he notes. But Simons adds that testing three measures, instead of just one, increased the likelihood of finding an improvement. And it remains unclear how test performance in a laboratory setting might translate to real-world situations. The outcome, Simons notes, "needs to be repeated, ideally with a much larger group, before it's treated as a strong finding."

For now, Wais says, the team hopes its studies with similar-sized groups will help draw funding to test the game in a larger pool of participants.

—Carolyn Wilke

Sometimes *Mindlessness* Is Better Than *Mindfulness*

In some situations, don't pay so much attention

By Alexander P. Burgoyne and David Z. Hambrick

Lukas Miglinas Alamy

Alexander P. Burgoyne earned his Ph.D. in cognition and cognitive neuroscience at Michigan State University in 2019. He is currently a postdoctoral research fellow in the Attention & Working Memory Lab at the Georgia Institute of Technology. **David Z. Hambrick** is a professor in the department of psychology at Michigan State University. His research focuses on individual differences in cognition and the development of expertise.

"Be present." This is the mantra of mindfulness meditation and a supposed key to self-awareness and acceptance. In one type of mindfulness exercise, the goal is to perform routine activities with a heightened sense of attention. "Try to take the time to experience your environment with all of your senses—touch, sound, sight, smell and taste. For example, when you eat a favorite food, take the time to smell, taste and truly enjoy it," recommends one Mayo Clinic article.

Mindfulness may indeed have psychological benefits. Earlier this year a synthesis of randomized controlled trials revealed that mindfulness-based interventions had small to moderate benefits for a number of health outcomes, including stress, anxiety and depression. That said, the effects of mindfulness were smaller and less consistent when compared with those of other therapies, and some effects appeared to fade months after the intervention. Taken together, the results suggest that mindfulness-based interventions may be better than nothing for some outcomes but that more research is needed to compare mindfulness with other therapies.

One thing the mindfulness-based interventions had in common is that they all attempted to cultivate focus on the present moment via multiple sessions of meditation practice.

Although mindfulness has its merits, psychological research has also revealed that in some circumstances it's important to be mindless. That is, as we develop skill in complex tasks, we can perform them with increasing facility until attention seems to be unnecessary. Everyday examples range from riding a bike to chopping cucumbers to brushing your teeth.

Underlying this state of "automaticity" (as cognitive psychologists call it) are mental processes that can be executed without paying attention to them. These processes run off without conscious awareness—a chain reaction of mental events. We don't perform all tasks automatically, but many can be performed this way once they are well practiced.

To be clear, paying attention is important when learning a new skill. In a study of our own, we found that measures of cognitive ability that tapped the capacity to focus attention predicted novice pianists' ability to learn and play "Happy Birthday to You."

But expertise research has also revealed that paying too much attention to what you're doing can have damaging effects, particularly when you perform well-practiced skills. In fact, this is one reason why some experts appear to "choke under pressure": they think too much about the mechanics of the task at hand.

In a classic study, cognitive scientist Sian Beilock and her colleagues had skilled golfers attempt to sink putts under different experimental conditions. In one scenario, the golfers were simply instructed to pay attention to the swing of their club and say "stop" when they finished their swing. In another condition, they were instructed to listen for a target sound while ignoring other noises and say the word "tone" when they heard the target sound.

Counterintuitively, the skilled golfers performed substantially worse when they focused on their swing than when they paid attention to irrelevant sounds. The effect of paying attention to their swing was so damaging that the golfers actually did better when they were warming up before the experiment began.

More recently, psychologist Yannick Balk and his colleagues had golfers try different interventions designed to mitigate the effects of performance pressure. The researchers induced performance pressure by videotaping the participants, telling them that their score sheets would be posted publicly at the clubhouse and incentivizing strong performance with coupons to the golf shop.

Without an intervention, the golfers performed significantly worse under pressure. Yet participants who were encouraged to think about something else—specifically, a song they knew by heart—improved when the stakes were high. It is worth cautioning that these results should be replicated in larger samples and across different contexts.

Nevertheless, the important message from this research is that focusing too carefully on the execution of well-practiced motor sequences can cause mistakes. Of course, we should not be resigned to go through life on autopilot, missing opportunities to make deeper connections with ourselves, one another and our environment. But there are situations where we should let automaticity take over. The next time you ride a bike, don't overthink it. **M**

Why Sports Concussions Are Worse for Women

As women's soccer, rugby and other sports gain popularity, scientists are racing to understand how the female brain responds to head injury

By Katharine Sanderson

Soccer players jump for a header at a UEFA women's Champions League match in Décines-Charpieu, France, in March 2019.

Jeff Pachoud *Getty Images*

Katharine Sanderson is a freelance journalist based in Cornwall, England.

LIZ WILLIAMS WAS STANDING pitchside at a women's rugby match, and she did not like what she was seeing. Williams, who researches forensic biomechanics at Swansea University in Wales, had equipped some of the players with a mouthguard that contained a sensor to measure the speed of head movement. She wanted to understand more about head injuries in the brutal sport. "There were a few instances when my blood went cold," Williams says.

When the women fell in a tackle, their heads would often whiplash into the ground. The sensors showed that the skull was accelerating—indicating an increased risk of brain injury. But medical staff at the match, not trained to look out for this type of head movement as a cause of injury, deemed the women fine to play on. Such whiplash injuries are much rarer when males play.

Williams's observations highlight an increasingly apparent problem. A growing body of data suggests that female athletes are at significantly greater risk of a traumatic brain injury event than male athletes. They also fare worse after a concussion and take longer to recover. As researchers gather more data, the picture becomes steadily more alarming.

Female athletes are speaking out about their own experiences, including Sue Lopez, the U.K.'s first semiprofessional female soccer player in the 1970s, who now has dementia—a diagnosis she has linked to concussions from heading the ball.

Researchers have offered some explanations for the greater risk to women, although the science is at an early stage. Their ideas range from differences in the microstructure of the brain to the influence of hormones, coaching regimes, players' level of experience and the management of injuries.

Given that most, if not all, sports-concussion protocols are based on data from men, female athletes ranging from schoolgirls to this year's Olympic soccer squads are being put at risk of serious injury. "We take all of these data, primarily from studies on men; we apply them to women. That's just got to change," says Michael Grey, who researches rehabilitation neuroscience at the University of East Anglia.

Head injuries in sports have had a high profile for many years, with hundreds, if not thousands, of participants in football, rugby, soccer, boxing and other sports experiencing dementia or memory loss thought to be linked to recurrent blows to the head decades earlier. Coaching protocols at all levels are changing to try to prevent injury, but these have generally neglected to include a huge cohort: women.

BIGGER RISK

Studies from U.S. collegiate sports have shown that female athletes are 1.9 times more likely to develop a sports-related concussion than are their male contemporaries in comparable sports. Those female students also missed many more study days as they recovered. Neuropathologist Willie Stewart of the University of Glasgow co-authored a study published earlier this year of more than 80,000 secondary-school soccer players in the U.S., with similar results.

It's not just the number of head injuries that differs between women and men but also their nature. A review of 25 studies of sports-related concussion suggests that female athletes not only are more susceptible to concussion than are males but also sustain more-severe concussions.

Athletics trainer and sports scientist Tracey Covassin of Michigan State University was one of the first to look at the differences between the sexes, starting in the early 2000s. She was interested in concussion, but noticed that all the data were coming from male-dominated sports in the U.S.: ice hockey, boxing and football. In more than 20 papers over almost two decades, Covassin has shown that there are sex differences in concussion rates and recovery times. In 2013, for instance, she published work on concussed soccer players in the U.S., and showed that the female players scored lower in memory tests and experienced more symptoms than did their male contemporaries.

As yet unpublished research by Williams on female

rugby players—among the first studies to analyze sex-specific mechanisms of head injury in the sport—showed that more than 50 percent of the 25 female participants experienced injuries caused by their head whiplashing into the ground, whereas only one male player did. “I didn’t expect that. That’s an important discovery,” says Grey, who has seen Williams’s results.

The actions leading to head injuries in female players might also be different. In Stewart’s soccer study, the girls were most likely to injure themselves when they made contact with an object (such as the ball, when heading it for example), whereas the boys were more likely to make contact with another player. Whether this is a matter of coaching, an individual’s level of playing experience or something else isn’t yet known.

WHY WOMEN FARE WORSE

The damage that causes concussion can be quite subtle. The brain can’t move that much in the skull, Stewart explains. “The brain virtually fills the intercranial cavity, and there’s a little thin film of fluid that fills up what space is left.” But, in the split second after an impact, the head rapidly decelerates, and the resulting forces transmit deep inside the brain. The gelatinous gray matter undergoes significant shear forces when the head stops suddenly, pushing and pulling the brain tissue in a way that can cause structural damage.

And those forces can affect the brains of men and women in profoundly different ways. Doug Smith of the University of Pennsylvania’s Penn Center for Brain Injury and Repair uncovered evidence that could be crucial for explaining some of the different outcomes seen in women versus men: their brain cells are structurally different.

Every neuron has a major fiber called the axon, which is responsible for transmitting electrical signals from cell to cell. Damage to axons, through strong shear forces, is thought to be the main reason that concussions occur. “Your brain literally can break,” says Smith, holding up some silly putty during a video call to demonstrate. When stretched gently, the silly putty deforms and then relaxes back into shape. When yanked violently, it snaps.

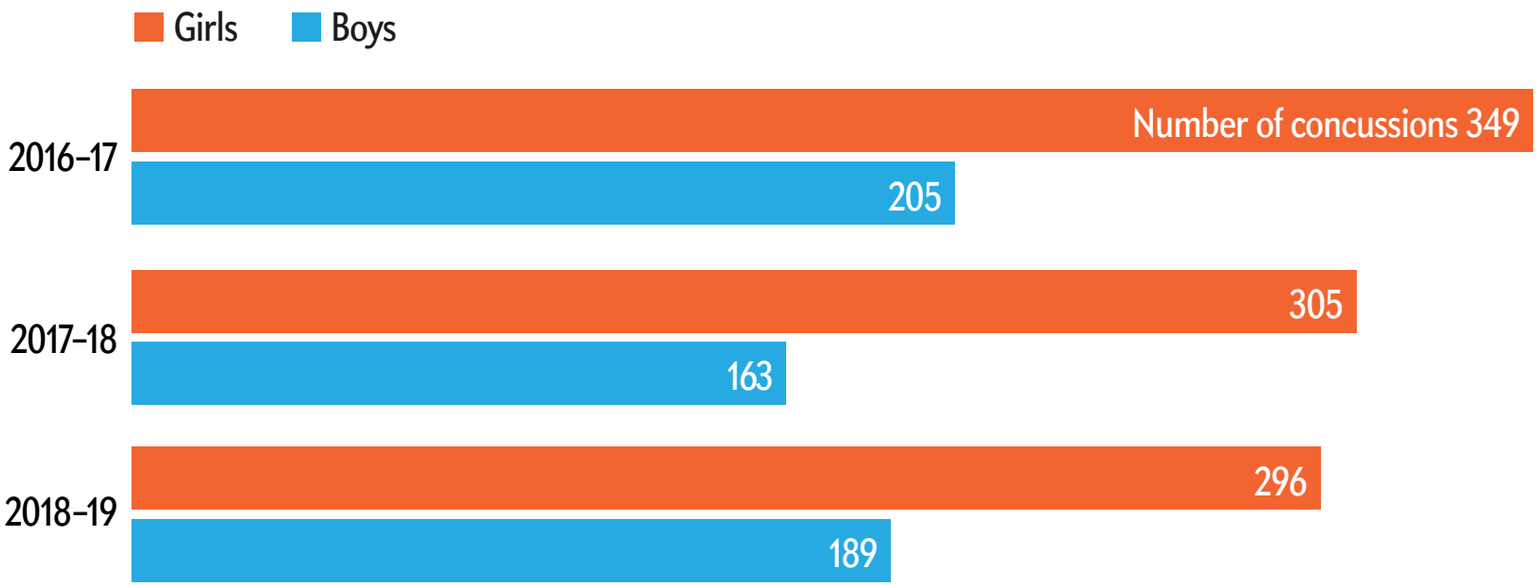
Inside each axon, tiny protein tunnels, called microtubules, that give cells their structure behave similarly, Smith says. These microtubules, only 25 nanometers wide, carry proteins in the axons and help them to function. If a microtubule is damaged, its protein cargo builds up, causing inflammation and ultimately a breakage, Smith explains. “And if you disconnect an axon, it’s gone forever.”

Smith’s team knew from imaging and brain-tissue studies that axon fibers from the brains of female rats and humans are slimmer than those from males. They wanted to know more about the differences and what effect they might have on brain injury, so they cultured rat neurons and then damaged them by exposing them to a rapid air blast. In the neurons from female rats, the axons were smaller and the microtubules narrower and more susceptible to damage than in the cells from males. The same was true for cultured human neurons.

Knowing the extent of axonal damage could be an indicator of how well someone could recover from a concussion. In a sports setting, this could be used to determine when an athlete is safe to return to the field, perhaps in the form of a blood test. Smith is now trying to find biomarkers of axonal damage in the blood—for instance, proteins that leak from axons when they are harmed. He’s doing studies on professional ice hockey players and measuring axonal protein levels in blood before and after injury. “We did find out that some of these proteins and protein fragments, at a certain level, will actually

Concussion Risk

A survey of more than 80,000 secondary-school soccer players in Michigan found that girls are nearly twice as likely as boys to experience concussions.



Source: Bretzin et al. *JAMA Network Open* 4, e218191 (2021).

Nature; Source: *Bretzin et al., 2021*

predict who's going to have a poor outcome," Smith says.

Grey urges caution in extrapolating too much from Smith's work on neurons in culture, which is mainly in rats. "Now that's not to say that I disagree," he adds. "It's just that we need to be cautious. This is one study. I personally think there are other issues that are more important."

One of those might be differences in neck strength, which some researchers think could have a considerable role in mitigating the damage wrought by concussion. Williams's mouthguard study also measured neck strength to see what sex differences there are. She found that female players' necks were 47 percent weaker than men's. Williams is working on improving neck strength in female rugby players to understand whether specific training could lessen the likelihood of concussion.

Not everyone agrees, however, that neck strength is the problem, or the answer. Stewart isn't convinced by any of the studies showing that neck strength is a factor in increasing the risk of a concussion, or a factor in improving the outcome of concussions.

Some researchers, including Grey, favor the idea that concussion is aggravated by the hormones that govern the menstrual cycle.

In 2014 Jeff Bazarian, a physician specializing in brain injury at the University of Rochester Medical Center, published a paper that showed a clear correlation between the menstrual cycle and how women recover from a traumatic brain injury. His team found that women who arrived at the emergency department with a head injury sustained while they were in the luteal phase of the menstrual cycle, which begins after ovulation and is when progesterone levels are highest, fared worse a month later than did women who hit their heads during the follicular stage, which marks the start of a new cycle and ends at ovulation. Women who were taking oral contraceptives, which balance out hormone levels, also fared better.

A doctor examines an athlete for injuries during a boxing match at the Tokyo Olympics in July 2021.

Ueslei Marcelino *Getty Images*

Initially this seems counterintuitive because progesterone has been shown to have a neuroprotective effect, and the luteal phase is when that hormone peaks. But other studies have reported an association between progesterone and concussion. Martina Anto-Ocrah, a reproductive epidemiologist at the University of Rochester, who has continued Bazarian's work, says this is because the brain injury causes progesterone levels to abruptly plummet.

Anto-Ocrah became interested in concussion and female sexual health after seeing evidence from the National Football League that some 30 years after sustaining concussions, male athletes were experiencing low testosterone levels and erectile dysfunction. "But there was nothing in the literature for women. I started think-

ing, why are we not looking at how concussion affects female reproduction, female menstruation, female sexual health?" she says.

Anto-Ocrah is discovering signs that not only does the menstrual cycle have an impact on concussion but, conversely, that head injuries can affect the menstrual cycle and other aspects of reproductive function by interfering with the brain regions that, in tandem with other glands in the body, help to control levels of estrogen and progesterone.

TREATING WOMEN DIFFERENTLY

One thing scientists agree on is the need for more research about women who sustain head injuries. In sports, this could transform the concussion-treatment protocols, recovery experiences and the return to play. In July, World Rugby, rugby union's global governing body, made a statement committing to conduct research into injury-prevention programs specific to women, and stressing the need for such initiatives. Grey says he knows of no sports bodies that have actually implemented female-specific concussion measures or protocols.

Research funders are beginning to recognize the need to study sports concussions separately in men and women. The National Institute of Neurological Disorders and Stroke has allotted a total of $6.8 million over five years to two large projects studying sex differences in concussion and its assessment.

As part of this push for more data, in 2019 Stewart and his collaborator Katherine Snedaker, who runs PINK Concussions, an advocacy group for women's head injury, put out a call for more female athletes to pledge their brains to the Glasgow traumatic brain-injury archive he curates. Stewart's team plans to use the archive to investigate further how traumatic brain injury harms brain tissue and alters gene expression, and how it might go on to cause degenerative brain disease. Of the 1,800 or so donated brains in the archive, 75 percent are from men. Fewer than 200 are from athletes, and none of those is from a woman, although a number of high-profile U.K.-based female athletes have pledged their brains, including Scottish soccer player Rose Reilly, judo international Connie Ramsay and Scottish rugby star Lee Cockburn.

Prompted by what she saw on the pitch and facing some enforced downtime during the COVID-19 pandemic, Williams put together a survey of almost 2,000 female rugby players from 56 countries, who answered questions about their experiences of concussion. Early results suggest that players vary hugely in their knowledge of how to recognize and deal with brain injuries.

Williams says that her work, and that of others, is slowly gaining traction. In April the University of Otago in New Zealand announced the start of a study in collaboration with World Rugby that will use a mouthguard to quantify aspects of head injuries in both male and female rugby players.

There are bright spots, but at the moment, Grey says, sports bodies mostly ignore the steadily building knowledge about sex differences in concussion. The male game is still the priority, Stewart says. "There's this general focus on male sport, male injury and male outcomes, and less on female. It's terrible neglect." **M**

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Daniel R. George and **Peter J. Whitehouse** co-wrote *American Dementia: Brain Health in an Unhealthy Society* (Johns Hopkins University Press, 2021).

NEUROLOGY

Alzheimer's, Inc.: When a Hypothesis Becomes Too Big to Fail

This summer's controversy surrounding the FDA's shocking approval of the drug aducanumab provides a window into a scientific field in crisis

Rhys Hayward *Getty Images*

Aducanumab, marketed as "Aduhelm," is an antiamyloid monoclonal antibody and the latest in a procession of such drugs to be tested against Alzheimer's disease. Over the past several decades, billions have been spent targeting the amyloid that clumps together to form the neuritic plaques first documented by German psychiatrist Alois Alzheimer in 1906. This class of drugs has reduced amyloid aggregation; however, since 2000, there has been a virtual 100 percent fail rate in clinical trials, with some therapies actually worsening patient outcomes.

In 2019 aducanumab failed in a futility analysis of two pooled phase III randomized controlled trials, but was later claimed to have yielded a small benefit for a subset of patients in a high-dosage group. The biologic was granted accelerated approval by the FDA based not on its clinical benefit but rather on its ability to lower amyloid on PET scans. Biogen immediately priced the treatment at $56,000 annually, making it potentially one of the most expensive drugs in the country's history.

This predicament is all the more surreal because—in the absence of more decisive evi-

dence—there is no adequate proof that the drug actually clinically benefits people who take it. Aducanumab, which is delivered intravenously, was observed to cause brain swelling or bleeding in 40 percent of high-dose participants as well as higher rates of headache, falls and diarrhea. The FDA's decision flew in the face of a near-consensus recommendation from its advisory committee not to approve. Three members of that committee have since resigned; several federal investigations have been launched to examine the close relationship between Biogen and the FDA; and the Department of Veterans Affairs and numerous private insurers and high-profile hospital systems have already signaled they want nothing to do with the drug. Meanwhile Biogen has launched a Web site and comprehensive marketing campaign called "It's Time," quizzing potential consumers on their memory loss and ultimately guiding them to experts, imaging and/or infusion sites.

The aducanumab debacle is a microcosm of how the medical-industrial complex has taken hold within the Alzheimer's field for decades, distorting science and policy while limiting other promising avenues of research and action on brain health and the care of persons living with dementia.

At the heart of this problem is that the field has ossified in decidedly unscientific fashion around the amyloid cascade hypothesis—that is, the belief that amyloid is toxic and initiates processes disrupting cell function. This has funneled federal, foundation and pharmaceutical/venture capital funding disproportionately into amyloid research despite the fact that the protein's causal role remains unclear. Indeed, up to 40 percent of people in their 70s have amyloid deposits but normal cognition. It remains a possibility that amyloid deposits are not themselves causal but rather are part of the brain's injury response.

Moreover, despite its singular label, "Alzheimer's" is increasingly understood as a heterogeneous syndrome involving not merely the hallmark amyloid plaques and tau tangles but other features such as vascular changes. A majority of clinical "Alzheimer's" cases are, in fact, actually observed to be mixed dementias. It is perhaps unsurprising that "attacking" one aspect of that syndrome (amyloid) has not "cured" Alzheimer's; however, it is surprising to witness the field's inability to modify or abandon the amyloid hypothesis in light of contravening evidence. Such is the stultifying effect of the medical-industrial complex, which has aligned incentives with fame and fortune based on the pursuit of single-mechanism drugs rather than the clear-eyed scrutiny demanded by the scientific method.

Constituted in this narrow fashion, the field's agenda has been controlled by gatekeepers—whom some have referred to as the "Alzheimer's cabal"—who have exerted strong downward pressure to endorse the amyloid hypothesis. Journals, conferences and professional societies promote and reward research endorsing the conventionally accepted premises. Careers are built and consulting opportunities gained by amassing publications and funding based on received wisdom. Meanwhile those challenging the dominant agenda have been marginalized, with funding flowing away from other plausible theories of causation. To question whether it is even reasonable to expect biotechnology to cure a condition as complex and intimately age-related as Alzheimer's syndrome has been treated as heresy.

The reductive molecular, industry-driven approach has also narrowed imaginative thinking about how to adapt to the challenges we face as an aging society. As we write in our forthcoming book *American Dementia* (Johns Hopkins University Press, 2021), one of the most compelling recent research findings is that dementia rates have been in decline in the U.S., Canada, the U.K., France, Sweden and the Netherlands over the past decade.

This trend has little to do with biotechnology and much to do with mid-20th-century public policy. It increased total years of education for those now in their retirement years (via the G.I. Bill and investment in state colleges and universities in the U.S.), expanded health care and improved treatment of risk factors that affect the brain (that is, vascular disease, high cholesterol), created remarkably successful smoking-cessation programs, and legislated the deleading of gasoline. In combination, these state actions in service of public health are believed by most experts—including the *Lancet* Commission on dementia prevention—to have enhanced the cognitive reserve of today's older adults.

A field not captured by industry might ask whether 21st-century governments are capable of engendering such population-level actions focused on improving larger institutions, structures

and social processes that benefit brain health. Arguably, achieving universal health care and higher education and addressing the nation's aging water pipe infrastructure (which has yielded a modern-day lead crisis) could be expected to make similar contributions to brain health across decades. So, too, would provision of long-term care insurance provide material security for elders who currently live in a precarious situation wherein the U.S. government won't pay for care through Medicaid until they spend down essentially all their assets.

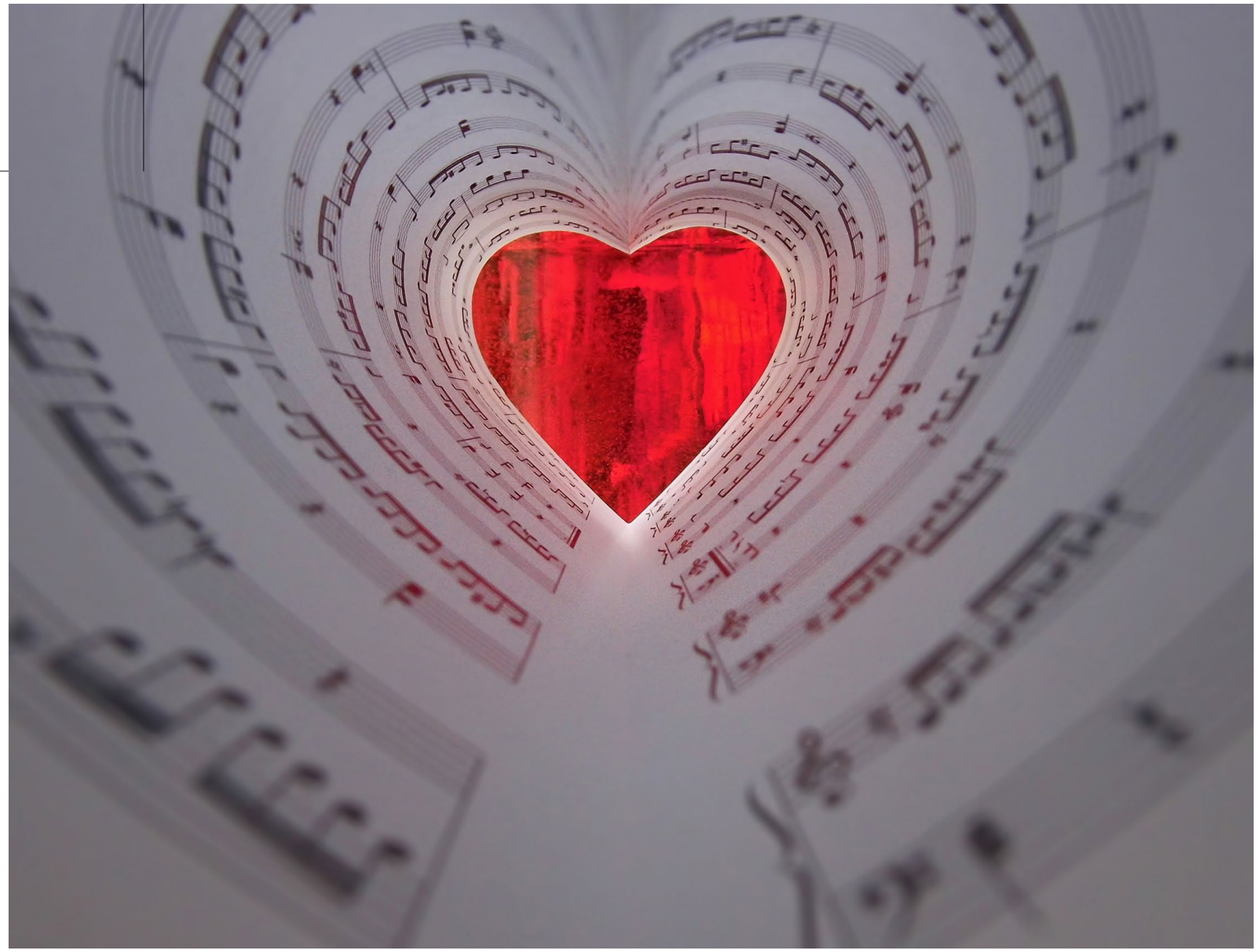
Moreover, we have observed in our combined seven decades of work the profound effects of the arts in dementia-care environments. Music, dance, storytelling, expressive artwork, gardening, intergenerational activities, pet therapy and other creative, relationship-oriented approaches that tap into quintessential elements of our humanity improve quality of life for elders and their caregivers far more than current drugs, including aducanumab. These "socialceuticals" deserve our investment even if they are not commodities that will always generate revenue for industry.

Ultimately aducanumab reflects the forces that have led the Alzheimer's field astray in the 21st century. When industry drives research incentives and when a hypothesis becomes "too big to fail," we squander scarce resources, lose precious time, and fail to properly adapt to one of the major challenges of our era.

MEDICINE

How Music Can Literally Heal the Heart

Its structural attributes and physiological effects make it an ideal tool for learning cardiology, studying heart-brain interactions and dispensing neurocardiac therapy



Dragan Todorovic Getty Images

In a maverick method, nephrologist Michael Field taught medical students to decipher different heart murmurs through their stethoscopes, trills, grace notes and decrescendos to describe the distinctive sounds of heart valves snapping closed and blood ebbing through leaky valves in plumbing disorders of the heart.

Separately, in music based on electrocardiographic (ECG) traces of heart rhythm disorders, one of us—musician-mathematician Elaine Chew—used music notation to capture the signature rhythms of electrical anomalies of the heart. Collaged from extant music fragments matching the heartbeats, Brubeck's *Blue Rondo à la Turk* provided the 2:4:3 rhythmic tattoo of ventricular early beats, Piazzolla's *Le Grand Tango* remixed produced the irregular rhythms of atrial fibrillation. *Little Etudes for piano*, with pedagogical descriptions by cardiologist Pier Lambiase, provided a layperson's introduction to electrical aberrations of the heart.

The reason these heart-music mappings work is because abnormal heart rhythms tend to form simple interbeat-interval ratios. In fact, the distinctive rhythms in Beethoven's music so closely resemble those of heart rhythm disorders that cardiologists have speculated that they may be transcriptions of Beethoven's possible arrhythmia, his interoceptive awareness of his own heartbeat enhanced by his deafness.

This is but one of multiple reasons music should be part of every heart physician's tool kit. Music and the heart have been romantically linked in popular consciousness because of their shared connections to human emotions and the brain. History is replete with examples of emo-

tionally charged events followed almost immediately by the death of the person. Surgeon John Hunter famously pronounced, "My life is at the mercy of any scoundrel who should put me in a passion," before collapsing and dying after a heated board room meeting.

Cardiologists Peter Taggart and Pier Lambiase have been studying how emotions alter the conductive properties of individual heart cells. Mental stress changes the recovery period of heart cells after each heartbeat, called the action potential duration. Taggart co-authored a study in which patients whose hearts were paced at a steady rate watch the harrowing "cut the rope" scene from *Vertical Limit* (2000). The patients' action potential duration shortened under the stress. This may explain how more extreme stress coupled with underlying cardiac disease could precipitate life-threatening arrhythmias.

Acute stress produces dramatic effects in the heart, but slow-burning chronic stress because of protracted insecurity also predisposes sufferers to disease and mortality. The sympathetic nervous system's default state of high alertness is suppressed when safety is perceived; these safety brakes are lifted under duress. "Generalized Unsafety Theory of Stress," co-written by psychophysiologist Julian F. Thayer, links the unconsciously perceived unsafety of prolonged stressors such as low social status, early life adversity or loneliness to hypervigilance that increases the odds of developing heart disease.

Music moves us in part because it draws on our primal intuitions about the heartbeat. Until the mid-19th century when it was replaced by the mechanical metronome, the human heartbeat provided the standard unit of measure for musical time. In his 1496 treatise, the *Practica Musicae*, composer-theorist Franchinus Gaffurius wrote that the proper measure of the musical beat should be the pulse of a healthy human, noting that the pulses of "fevered persons" undergo an increase or become unequal in ways that worry physicians.

When we connect to the pulse of the music, we sense another's physiological states. The steady pulse at the beginning of Schubert's *Trio, Op. 100* sets a strong but serene pace for its haunting melody. The breathless octaves in the opening of *Der Erlkrönig* evokes the rapid heart palpitations of the fevered boy in his father's arms, galloping through the stormy, windswept night. Hearing just heartbeats, pulse-only music, has been found to increase listeners' ability to sense what others are feeling in a study co-authored by musician-scientist Grace Leslie.

Music changes our heart rates, breathing and blood pressure and alters our heart rate variability, indicators of cardiac and mental health. Neuroscientist Psyche Loui and her colleagues have traced music-induced physiological changes to a central node in the brain's networks, called the anterior insula, with dense connections to the vagus nerve, responsible for unconscious regulation of body functions.

The anterior insula is associated with empathetic mirroring of external and internal experiences. It is also connected to parts of the brain responsible for hearing (the auditory cortices) and for pleasure (the dopaminergic reward system). These auditory and reward network pathways likely subserve the mind's ability to form predictions and expectations during music listening. The systematic fulfilment and violation of expectations are thought to underlie emotion and meaning in music.

Music is an ideal catalyst for inducing physiological changes in heart-brain studies because it can be dissected systematically into features based on note content and the way this content is communicated in performance. Evidence suggests that these musical attributes trigger brain responses at a basic level. Analyzing listeners' brain-imaging data in the OpenFMRI Study Forrest data set, composer-neuroscientist Michael Casey found that specific music features induced predictable activation patterns in regions of listeners' brains. The activation patterns were consistent enough for machines to infer the music the listener heard or its genre simply from their functional MRI scans.

Music features have also been linked to physiological responses. In a study co-authored by physicians Luciano Bernardi and Peter Sleight, loudness increases in vocal and orchestral music produced vascular constriction and blood pressure increases proportionate to these crescendos. Verdi arias with 10-second-long phrases—the period of Mayer waves, the body's natural blood pressure oscillation—caused listeners' heart and respiratory signals to sync with the music envelope. Such unconscious physiological responses are thought to be the progenitors of music-induced emotions.

Music also has a communal impact on human physiology. People listening to the same music tend

to synchronize not only their movements but also their breathing and heart rhythms. Some of this heartbeat coherence is result of breathing together, but partial coherence (linear relationships) remained higher between the heartbeats of people vocalizing long notes together, over the baseline or breathing together, even after removing the effect of respiration.

The cognitive and physical demands of playing music also have measurable effects on musicians' heart rhythms and breathing patterns. Psychologists Caroline Palmer and Shannon Wright showed that repetitiveness of musicians' heart rhythms evince greater rigidity (predictability) when playing unfamiliar musical melodies, as welll as when playing first thing after waking in the morning rather than in the evening.

For cardiac patients, music-based interventions can also modulate cerebral blood flow, reduce preoperative anxiety and postoperative stress, improve surgery outcomes, and lower cortisol levels. Music interventions are found to significantly affect heart rate and blood pressure in coronary heart disease patients. Listening to relaxing music reduced not only heart and respiration rates but also oxygen demand of the heart in patients who have had a heart attack.

Technological advances in biofeedback sensors means physiological parameters such as heartbeats and heart rate variability can be harnessed to guide music interventions in cardiac therapy. Physiological feedback can be used to select or shape music to influence listeners' heart rates and breathing, for example, to increase heart rate variability. With widespread adoption of biofeedback devices, the tailoring of music interventions to individual cognitive or neural-cardiac states is well within reach, enabling a "musical prescription" for improved mental and physical well-being.

Elaine Chew is a pianist-mathematician and principal investigator of the European Research Council–funded project COSMOS at the French National Center for Scientific Research, where she is based at the Sciences and Technologies of Music and Sound Laboratory located at the Institute for Research and Coordination of Acoustics/Music.

Psyche Loui is a neuroscientist-violinist and an associate professor and director of the Music, Imaging, and Neural Dynamics (MIND) Laboratory at Northeastern University.

Grace Leslie, a flutist, electronic musician and scientist, is an assistant professor of music technology at the Georgia Institute of Technology, where she directs the Brain Music Laboratory.

Caroline Palmer is Canada Research Chair in the Cognitive Neuroscience of Performance and a professor of psychology at McGill University, where she directs the Sequence Production Laboratory.

Jonathan Berger is Denning Family Provostial Professor of Music and a Bass University Fellow in Undergraduate Education at Stanford University. He is a composer-researcher at the Center for Computer Research in Music and Acoustics.

Edward W. Large is director of the Music Dynamics Laboratory and the Theoretical Neuroscience Laboratory at the University of Connecticut, where he is a professor in the department of psychological sciences and the department of physics.

Nicolò F. Bernardi is a personal and professional coach and consultant who is trained as a cognitive neuroscientist, music therapist and yoga teacher.

Suzanne Hanser is chair emerita and professor of music therapy at Berklee College of Music and president of the International Association for Music & Medicine.

Julian F. Thayer, a bassist and composer, is Distinguished University Professor in the department of psychological science at the University of California, Irvine, and Ohio Eminent Scholar Professor in Health Psychology emeritus at the Ohio State University.

Michael A. Casey is a professor in the department of computer science and the department of music at Dartmouth College.

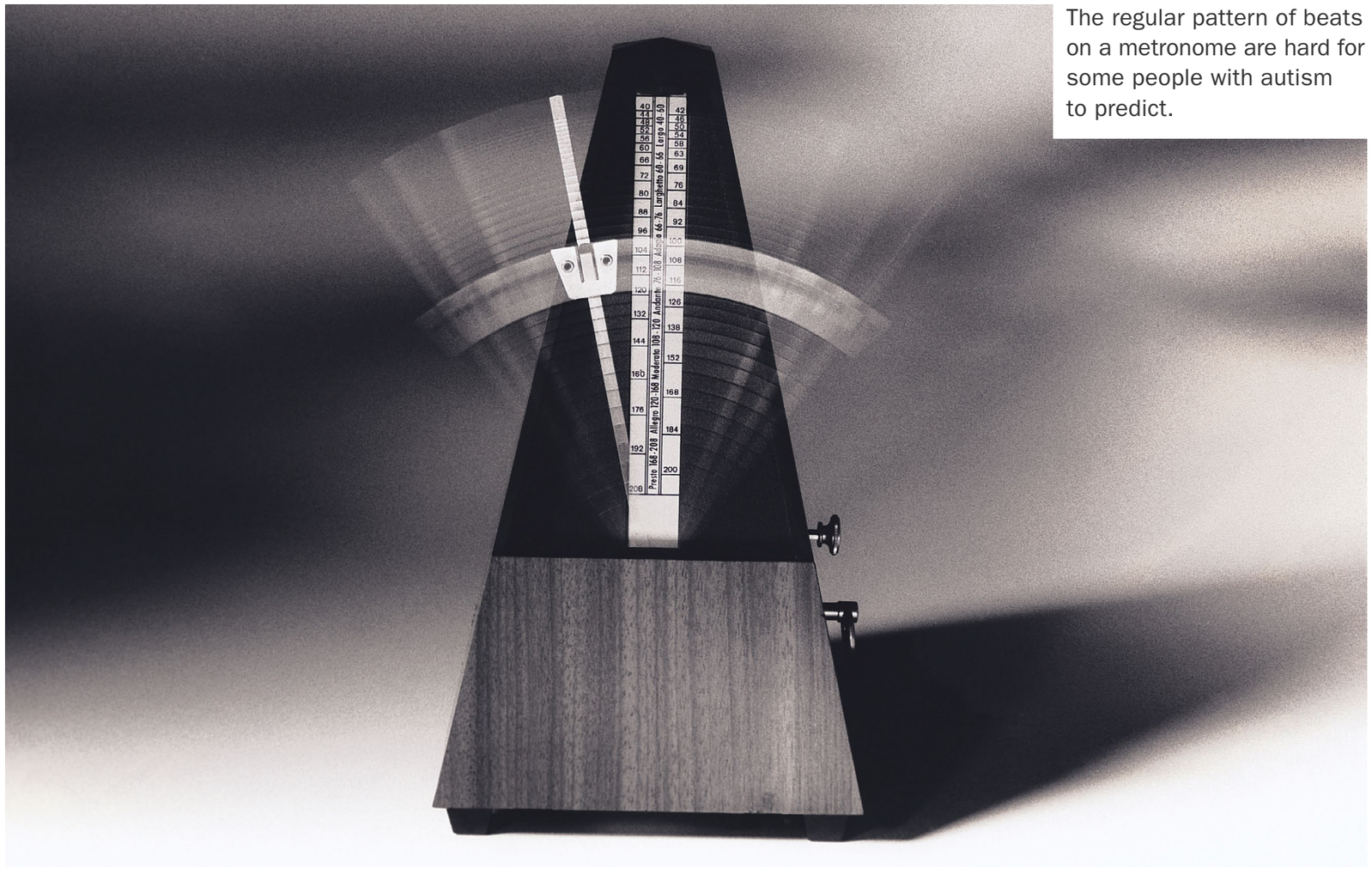
Pier D. Lambiase is a professor of cardiology at University College London Institute of Cardiovascular Science and Barts Heart Center and co-director of cardiovascular research at Barts Health NHS Trust.

Pamela Feliciano is scientific director of SPARK (Simons Foundation Powering Autism Research through Knowledge) and is a senior scientist at SFARI (Simons Foundation Autism Research Initiative). SPARK is a SFARI initiative that seeks to accelerate autism research through a vibrant and informative online platform that meaningfully engages individuals with autism spectrum disorder (ASD) and their families and connects them to interested researchers.

NEUROSCIENCE

A New Idea That Could Help Us Understand Autism

Some of the condition's most challenging traits might be explained by deficits in predictive skills



The regular pattern of beats on a metronome are hard for some people with autism to predict.

John Knill *Getty Images*

As social beings, when thinking about autism we tend to focus on its social challenges, such as difficulty communicating, making friends and showing empathy. I am a geneticist and the mother of a teenage boy with autism. I, too, worry most about whether he'll have the conversational skills to do basic things like grocery shopping or whether he will ever have a real friend. But I assure you that the nonsocial features of autism are also front and center in our lives: intense insistence on sameness, atypical responses to sensory stimuli and a remarkable ability to detect small details. Many attempts have been made to explain all the symptoms of autism holistically, but no one theory has yet explained all the condition's puzzling and diverse features.

Now a growing number of neurocognitive scientists think that many traits found in people with autism spectrum disorder (ASD) may be explained centrally by impairments in predictive skills—and have begun testing this hypothesis.

Generally, the human brain determines what's coming next based on the status quo, plus what we recall from previous experiences. Scientists theorize that people with ASD have differences that disturb their ability to predict. It's not that people with autism can't make predictions; it's that their predictions are flawed because they perceive the world "too accurately." Their predictions are less influenced by prior experiences and more influenced by what they are experiencing in the moment. They overemphasize the "now."

When the connections between an event and a consequence are very clear, people with ASD can learn them. But the real world is an ever changing environment with a lot of complexity and some-

times contingencies and deviations are as not as obvious. Many individuals with autism have difficulty figuring out which cues are most important because there are too many other cues complicating the environment and competing for attention.

Five years ago the Simons Foundation's autism research initiative launched SPARK (Simons Powering Autism Research for Knowledge) to harness the power of big data by engaging hundreds of thousands of individuals with autism and their family members to participate in research. The more people who participate, the deeper and richer these data sets become, catalyzing research that is expanding our knowledge of both biology and behavior to develop more precise approaches to medical and behavioral issues. Scientists are now recruiting SPARK participants to study directly observable aspects of prediction more closely. There are two components that can be observed: the ability to learn the connection between an "antecedent" event and its consequence, and responses to predictable events.

Pawan Sinha of the Massachusetts Institute of Technology recently published results from a study showing that people with ASD had very different responses to a highly regular sequence of tones played on a metronome than those without ASD. Whereas people without ASD "habituate" to the sequence of regular tones, people with ASD do not acclimate to the sounds over time. Rather their responses after several minutes of hearing the tone sequence were still as robust as they were when they were first played. Using SPARK's powerful digital platform, Sinha and colleagues are now able to conduct similar experiments online with a much larger number of people with autism.

As the researchers acknowledge, the connections between the decreased habituation and real-world challenges in people with autism are still not clear, but testing multiple aspects of prediction in more naturalistic contexts in a larger number of people will help address that knowledge gap. Eventually, a better understanding of the cognitive processes in autism may help to improve interventions—for example, by tailoring different prediction-based interventions to individuals with varying prediction styles.

Every parent of a teenager has their share of challenges, and, for me, an ongoing issue for my son is that he really seems to enjoy engaging in behaviors that will elicit a response from someone. Some of these "habits" have small consequences. For example, he loves to empty entire bottles of soap, detergent and cooking oil. He also likes to throw things out of his window. More than once, I've been out walking the dog and noticed pants on the roof of our house.

While one cannot deny the satisfaction inherent in dumping a lot of fine olive oil into a drain, it's impossible for me to ever fully understand why my son does any of these things. Still, I have a strong suspicion it's because he knows these behaviors will elicit a predictable response from me. I have learned that the more I respond, the more he will be encouraged to behave this way. So now when I find an empty bottle of detergent in the laundry room—or an entire roll of toilet paper in the bowl—I don't make a big deal of it.

Then comes the test of tests: one of his most problematic behaviors is touching our dog's rear end. He knows he is not supposed to do this. He knows that, most likely, someone might gasp aloud and then tell him to wash his hands. If his abilities to predict are impaired, then it makes sense that doing things that elicit predictable responses must be satisfying. Having a scientific framework that helps explain his behaviors helps me cope with them. More important, a better understanding increases my empathy for him, helps me explain his actions more clearly to others, and helps me remember not to react strongly.

Scientists are also using SPARK to test other aspects of prediction in autism, including language. Harvard University scientist Jesse Snedeker is recruiting participants from SPARK to test whether children with autism are less likely to make accurate predictions during natural language comprehension of simple sentences. These experiments will explore if children with autism differ in using linguistic context to predict upcoming words when hearing a story or conversation. The results will help scientists learn whether impairments in prediction in different people with autism are more broad or more specific to different domains.

As a parent and a researcher, my greatest hope is to help moms like me, children like Dylan, and families like mine. The challenges of understanding autism are many, but a better understanding of predictive patterns in autism will help us all—researchers and families—understand the many "whys" that remain a hallmark of autism.

Tamar Mendelson and **Laura Clary** are faculty members in the department of mental health at the Johns Hopkins Bloomberg School for Public Health. Mendelson is a Bloomberg Professor of American Health and directs the Johns Hopkins Center for Adolescent Health.

MENTAL HEALTH

Adolescent Mental Health? There's a "Vaccine" for That

School-based interventions that help students regulate their emotions in healthy ways have proved effective at preventing pandemic-related issues

Patrick T. Fallon *Getty Images*

Ask any teenager if they would like to talk about mindfulness and mood thermometers with their peers a dozen times in one school year, and most would decline the opportunity. But ask them instead if they would like a vaccine to ward off the worst mental health impacts of the past year and a half, and most would raise their hands without thinking.

Adolescence is a critical time for mental health, and most teens have an intimate relationship with stress. Before the pandemic, one out of every five U.S. teens developed a mental disorder, with half of all mental disorders occurring by age 14 and three quarters by the mid-20s. During the pandemic, approximately 40,000 children lost a parent, and many young people have been exposed to other traumas, such as food insecurity and homelessness, that increase risk for depression, anxiety and post-traumatic stress disorder. The pandemic will likely cause a spike in youth mental health problems, with long-term psychological fallout.

The good news is that, for youth, schools are an effective setting for preventing mental health problems. School-based interventions that enhance students' capacity to regulate their emotions in healthy ways, such as reframing a problem

positively, have proven effective at preventing or reducing mental health problems.

Our research offers one example: our team delivered a 12-session group prevention program called RAP (Relax, be Aware and do a Personal rating) Club to eighth graders in 29 Baltimore city public schools. Most schools served marginalized communities where poverty limits family prospects and youth are exposed to high rates of violence and other trauma.

RAP Club included mindfulness practices, such as breathing breaks with a "mood thermometer," to teach students nonjudgmental awareness of feelings and thoughts. Role-playing gave youth tools to promote positive communications. To demonstrate how pent-up stress affects the body, students shook up a bottle of seltzer until the liquid exploded; that was always a favorite.

Four months later assessments with RAP Club students showed they had significantly fewer trauma symptoms than students who did not participate. And group discussions with RAP Club students highlighted other benefits. They talked about improved coping. "I been dealing with stress way better…. Way, way better," said one boy.

Other students agreed. "When I get distressed … I used to smoke to get it off my mind. See now … I don't do it as much." "When I'm angry—I don't just snap on everybody."

Students saw changes in their sense of self. "I really used to have negative thoughts about myself, about the world…. Now I'm way more confident."

And they described improved mental health:

RAP Club included mindfulness practices, such as breathing breaks with a "mood thermometer," to teach students nonjudgmental awareness of feelings and thoughts.

"Depression went away from me…. I used to stay in my room a lot, listen to sad, depressing music, and just not talk to nobody. RAP Club … helped me—I dance more. I talk to my mother about everything now … we all happy and all that. Our life just changed."

COVID then provided an unexpected opportunity for a natural experiment. We contacted and assessed a subset of approximately 150 trial participants during the pandemic, one to four years after they completed our programming. Youth who did not take part in RAP Club showed increased anxiety during the pandemic, which makes sense. We are in extraordinarily stressful times.

But youth who participated in RAP Club, who learned how to manage the stress generated from the prepandemic hardships they faced, did not show a significant increase in anxiety. The program had provided a degree of immunization against this new batch of stress.

When this program began, we did not anticipate COVID-19 and the many ways it has disrupted childhood. As we dig deeper, though, we start to see the potential of mental health interventions to protect against negative impacts of future trauma exposure.

As a new academic year approaches, most policy makers and educators will look to "check the box" and provide some sort of programming, or teacher training, that acknowledges the emotional damage the pandemic has inflicted. But these new findings show urgency for programming that goes much further.

Schools need resources to deliver evidence-based programs in an ongoing fashion to promote and protect student mental health. These programs need to be culturally and developmentally appropriate and delivered in a coordinated fashion across grades K-12. While all students should receive universal group programming, more intensive services should be offered to those needing additional support. Finally, program evaluation is critical to assess whether programs are effective and for whom they work best. Partnerships with universities can support data collection and analyses. Students' and parents' perspectives on what works must also shape solutions.

In coordination with student vaccination efforts, school leaders and policy makers should leverage the potential for school mental health programs to serve as "mental health vaccines." As one of our focus group participants noted, "When you learn your feelings, you kind of find like inner peace. That happens, yeah." We owe it to our nation's youth to provide all the emotional protection we have available.

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CREATIVITY

To Solve the Environmental Crisis, We Must Foster the Power to Imagine

Our educational system is designed to generate productive workers, not creative thinkers and doers

Thomas Barwick *Getty Images*

Toward the end of my senior year at Dartmouth, I watched my peers line up in front of the Career Services building. Waiting for their interviews for corporate jobs, all seemed to be dressed the same—the men wearing navy jackets, the women dark dresses. I thought back to my first day on campus four years earlier when we all wore different colors and dreamed of different futures. It was as if our education, instead of enhancing our individualities and imaginations, had reduced them to sameness.

It was not a unique scene. All over the world, formal education supplies the economy with workers who will increase productivity. Its purpose is to fuel the economic machine rather than to alter its inner workings. But this machine now threatens our very survival. If the entire world reaches the levels of consumption seen in high-income countries today, we'll need multiple planet Earths to supply the resources. The absurd idea of infinite growth within a finite territory is at the heart of our economic system.

To keep this machine running, formal education generates ever more efficient "human capital." Increasing productivity metrics—such as revenue

per employee or return on investment—rather than the individuality of students drives our civilization's approach to schooling our young people. Whereas the Sustainable Development Goals call for turning education into a force for sustainability, the opposite is often true: the ways Western societies have come to think about education undermine our ability to deal with the environmental crisis. To get through this crisis, we need to cultivate our imagination, not undermine it.

Growing up, none of my schooling fostered my ability to imagine a world different from what I saw around me. As a child in 1990s Slovakia, I had to memorize textbooks word by word. Decades later, as an education researcher, I see children elsewhere going through the same—a chorus of Indian pupils repeating the sentences written by their teacher on the blackboard, a South African child yelled at by the teacher for failing to reproduce exactly the content of the textbook. Rote learning, discouraging individuality and instilling docility in children are still at the root of what it means to be educated across much of the world.

Many experts agree that we need to move away from such approaches to education. But the suppression of children's imagination doesn't take place only in underresourced communities or outmoded education systems. The issue is obscured but even more pernicious in "elite" institutions that tout "critical thinking." Save for a few wise mentors, hardly anyone encouraged me to imagine an alternative future for the world throughout my Ivy League undergraduate years and my Oxbridge graduate years. These institutions want to see their graduates succeed, and success is too often about maintaining current structures—not about reimagining their foundations.

All over the world, formal education supplies the economy with workers who will increase productivity.

In recent years we have witnessed efforts toward standardizing curricula across the globe. Such reforms bring Western notions of educational success to the rest of the world. Driven by the OECD's standardized tests, which rank education systems, countries focus on improving quantifiable outcomes such as literacy and numeracy. Winning the competition for the most efficient educational system today means having the most efficient workforce and growing the national economy faster tomorrow.

Our standardized, metric-driven, "efficient" education systems essentially shape children in the image of artificial intelligence. The perfect "worker," AI continually improves its own productivity but doesn't challenge the larger structures within which it operates. It is one of the great paradoxes of our time that we invest so much into building supercomputers while marginalizing the imaginative potential of millions of human brains.

Our focus on technological solutions to our civilization's challenges is driving our approach to education. More students at British universities are studying science, technology, engineering and mathematics (STEM) than ever before, including a 400 percent increase in enrollment in AI courses over the past 10 years. Compared with STEM, social sciences and humanities are often underfunded and seen as inferior by policy makers and the public alike. But this approach is counterproductive because non-STEM subjects are crucial to fostering our ability to reimagine the world.

We even put our hope in solving the environmental crisis on AI. We use machine learning to optimize energy networks, track land use through satellite imagery and predict extreme weather. But AI, like our other technologies, can only treat the symptoms of the environmental crisis, not the causes. These lie in our arrogance and lack of sensitivity to our impact on the planet. We can't outsource to computers the solutions to the flaws in our politics and culture that underpin the environmental crisis.

Throughout history, achievers of great change have relied on their imaginations to address fundamental flaws in society. In my country of birth, Czechoslovakia, dissidents against Communism kept their dreams of democracy alive for decades by imagining different futures. In South Africa under apartheid, Nelson Mandela's followers had to be radical in their imagination to create a vision of a fairer society. Imagining democracy when living under a totalitarian regime isn't that different from imagining degrowth when living in a world of infinite growth.

The kind of intelligence Nelson Mandela and Václav Havel possessed was not artificial. The ability to reimagine the future and disrupt the sta-

tus quo remains a distinctly human quality. Unlike AI, children are naturally imaginative and question the premises of society. In my research, I have observed that younger children are often the most radical in imagining different futures; as they get older, their imagination tends to become more generic, mimicking mainstream narratives of technological progress.

As long as our imagination is curtailed, ideas like degrowth or intergenerational justice remain fringe and sound utopian to many. Cultivating imagination means learning from history's disrupters who made the allegedly impossible palatable. It means moving away from our standardized curricula, quantifiable metrics and authoritarian pedagogies. Instead of dismissing "childish" ideas about the world's future, it means seeing inspiration in children's imaginations.

In an education system that celebrates imagination, arts and creativity are as important as math and science. Teachers develop and act on their own pedagogical philosophies. Children define success for themselves. Idealism coexists with pragmatism. Expressing opinions and taking political action are goals of education, not distractions from it. Some of these ideas have already inspired educational projects around the world—such as forest schools in Europe, jeevanshalas (schools of life) in India or Schumacher College in the U.K.—but these are the exceptions.

The environmental crisis is not a crisis of technology or science, it is a crisis of imagination. If we let children be our guides, we might just be able to imagine our way to survival.

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

The Twisted Paths of Perception

These patterned pavements make pedestrians watch their step

The King Pedro IV Square in Lisbon, Portugal, better known as the Rossio, regales visitors with a delightful exemplar of the traditional pavement called *calçada portuguesa*. Originally cobbled in 1848, the dizzying light and dark undulations symbolize the sea voyages of Portuguese navigators and predate 20th-century designs by Op Art creators such as Victor Vasarely and Bridget Riley, while inducing similar perceptions of flowing motion. But does the vibrant pattern stand in the way of safety?

A recent study from the University of Bristol in England asked participants how walking on floors patterned with visual illusions affected their discomfort levels and feeling of instability. Neuropsychologist Ute Leonards, who led the study, first considered the potential negative impact of such illusory patterns on walking

Dark and bright waves adorn the pavement of Rossio Square in Lisbon, Portugal.

during a visit to the iconic street of La Rambla in Barcelona, Spain. “I had noticed the 3-D effect of the floor patterns and wanted to add them to my collection,” she recalls. As Leonards photographed the waves in the paving design, an older gentleman approached her. “He said that he didn’t like the floor at all, as he wasn’t sure when his feet would actually hit the ground and how high he should lift his feet not to trip … he walked [as if] afraid that there might be black ice.”

Back in the laboratory, Leonards and her collaborators investigated the effects of four illusory patterns on people’s walking experience. Two of the designs, consisting of black-and-white alternating “furrows and ridges” modeled after the undulating pattern in Rossio Square, looked three-dimensional despite being printed on flat surfaces. More than half of the walkers found such designs aversive or uncomfortable to tread on, affecting their stability and even occasionally inducing fear of falling. The discomfort may lie in the mismatch between the sensory and physical characteristics of the walking environment. In nature, surfaces that look bumpy are generally bumpy, but this was not the case for the floor patterns examined in the study—a concern that may extend to a number of human-built environments.

The clue to avoiding the clash of art and accessibility, Leonards says, is to bring people into the planning process directly from the start and think of the project in a human-centered way. “I don’t think that this comes at the cost of aesthetics,” she explains, “but rather allows a far bigger group of people to enjoy beautiful places safely.”

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