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The Secret to Lasting Love

This cognitive ability enables couples to resolve their differences more quickly

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LIZ TORMES

In Love and Play

In 2014 mathematician Hannah Fry gave a TED talk where she presented the following set of equations that predicts the positivity of interactions between spouses:

$$W_{t+1} = w + r_W W_t + I_{HW}(H_t)$$
$$H_{t+1} = h + r_H H_t + I_{WH}(W_t)$$

Though they look complex, the two equations predict how each spouse will respond to the other depending on their respective moods and influence over each other. The reasoning goes that more positive interactions will lead to a more positive marriage. Couples everywhere seemed to have a simple prescription: be more positive than negative, and you'll have a better chance at success. Now a recent finding adds a neuroscientific element to the balance. As David Z. Hambrick and Daisuke S. Katsumata write, individuals who score high in working memory have less enduring conflict in their romantic relationships (see "How Research on Working Memory Can Improve Your Romantic Relationship"). This suggests that trying to resolve conflicts requires you to pay closer attention to what your partner is saying. And don't forget to stay positive as much as possible. And take out the trash more often.

In perhaps more lighthearted news, neuroscientists Ryan P. Dalton and Francisco Luongo describe in this issue a fascinating experiment in which rats were taught to play hide-and-seek while the researchers monitored their brain activity (see "Play May Be a Deeper Part of Human Nature Than We Thought"). Specific neurons in the prefrontal cortex associated with reward lit up during the game, suggesting that the brain's response to play is evolutionarily ancient. We are hardwired for fun, it seems. And that is a positive thought.

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On the Cover
This cognitive ability enables couples to resolve their differences more quickly

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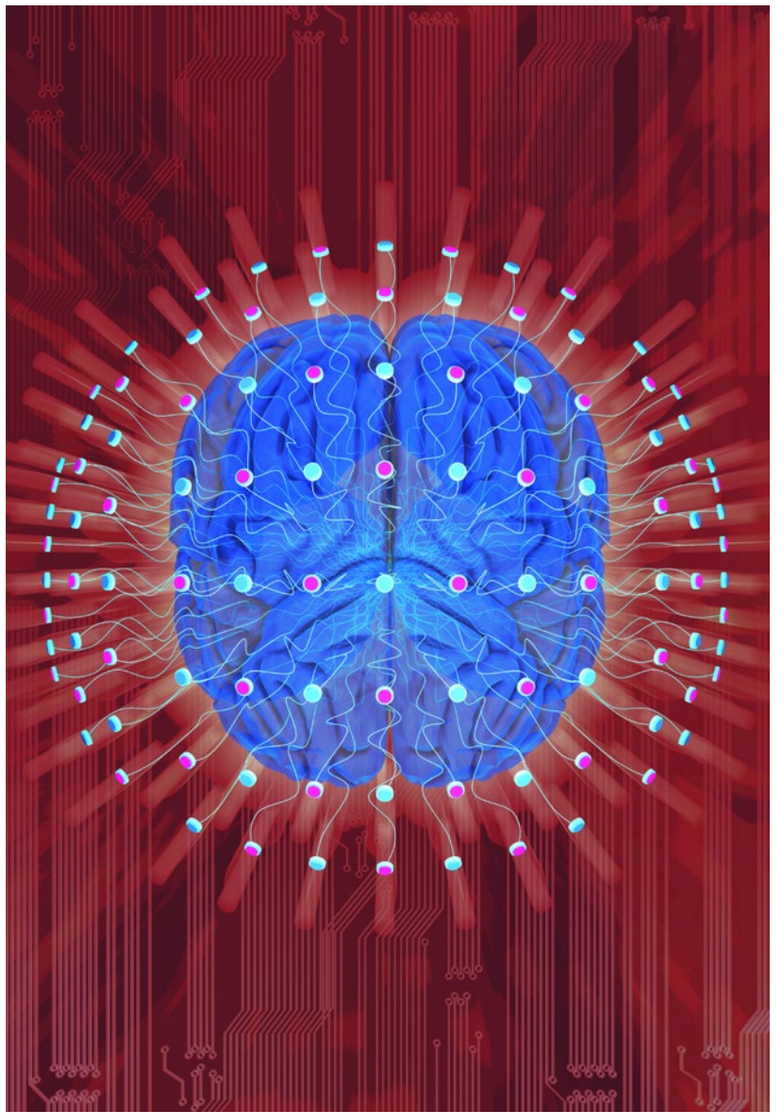

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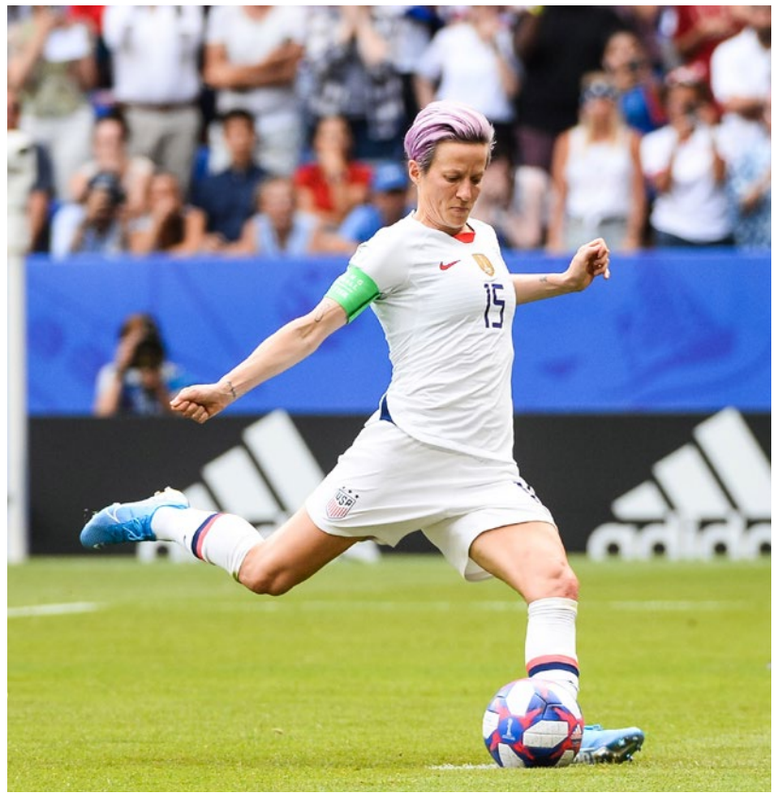

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How Research on Working Memory Can Improve Your Romantic Relationship

A cognitive factor helps explain how well we understand one another

Disagreements are virtually inevitable in a romantic relationship. More than 90 percent of couples argue, according to a survey by the University of Michigan's Institute for Social Research, with nearly half quarreling at least once a month. Common topics of marital disagreement are money, sex and time spent together. None of this will surprise anyone who has been in a long-term relationship.

But a new study indicates that a cognitive ability may help to explain why some couples are more successful in resolving their differences. University of North Carolina at Greensboro psychologist Levi Baker and his colleagues report that spouses who were high in working

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memory capacity had better memory for one another's statements in discussions about problems. In turn, these couples showed greater progress in resolving their problems over time. The study suggests that it's not just dogged commitment that gets couples through rough spots but a cognitive factor that directly affects the quality of partners' communication with each other.

The sample included 101 couples (93 heterosexual, seven lesbian and one gay) who had been married for less than three months. Working individually, the newlyweds first completed tests of working memory capacity, which is the ability to hold information in the focus of attention over a short period, as when following what someone is saying to you in a conversation. In one of the tests used by Baker and his colleagues, called operation span, the test taker sees an arithmetic problem on the screen and attempts to solve it, after which a letter appears. After some number of these trials, the person is prompted to recall the letters in the order in which they were presented.

Next, the couples participated jointly in problem-solving discussions. Each spouse identified a problem that could be resolved through changes in their partner's behavior. The couples were then left alone to discuss the problems, spending eight minutes on each and rating the severity of the problem before and after discussing it. After each discussion, the spouses went to separate rooms and were recorded attempting to recall each other's statements. Finally, after four and eight months, the couples were e-mailed questionnaires that asked them to again rate the severity of the problems.

Couples high in working memory capacity showed the greatest decline in problem severity at the follow-ups. Furthermore, spouses high in working memory capacity were the most accurate in recalling each other's statements from the discussions. Linking these two findings, when the researchers statistically controlled for spouses' memory for each other's statements, the relation between working-memory capacity and decline in problem severity dropped significantly.

Baker and his colleagues tested for the influence of other factors on their results, including self-control, tolerance for distress, and emotional regulation. None of these factors explained the relation between working memory capacity and decline in problem severity. While noting that other cognitive factors such as reasoning ability could also play a role in marital dispute resolution, the researchers suggested that a high level of working memory capacity contributed to decline in problem severity by facilitating encoding of the problem discussions into long-term memory.

A new study indicates that a cognitive ability may help to explain why some couples are more successful in resolving their differences.

These findings suggest that one way that romantic partners might better resolve their disputes is simply to pay better attention to each other when discussing problems. You have probably had the experience of being introduced to a person and not being able to remember their name seconds later. You didn't forget the person's name—you never committed it to memory. That is, you didn't pay enough attention to it to transfer it into your long-term memory. In the same way, if you don't attend to what your partner is saying when discussing a problem, you will remember it poorly, if at all. Making matters worse, in the absence of an accurate memory for the conversation, you may remember what you think your partner said rather than what he or she actually said, leading to a false memory. So listen carefully to your loved one and save discussions about relationship problems for times when the two of you are most attentive: when you are rested, sober and undistracted.

Conflict will always be a part of romantic relationships. Insights gained from this new research on the cognitive underpinnings of dispute resolution, however, may help partners resolve their differences more effectively and spend more time on the things that make a relationship worth having in the first place.

—David Z. Hambrick and Daisuke S. Katsumata

A Simple Test Predicts What Kindergartners Will Earn as Adults

Psychologists zero in on the skills that predict future success

Chances are you have heard about the "marshmallow test." Put a marshmallow in front of a child and give them two choices: eat it now or wait 15 minutes and get two. According to a classic study, children able to delay gratification and wait for the second marshmallow have better academic, social and health outcomes years later. Since these early experiments, researchers have shown that a wide range of childhood traits from social and emotional skills to motivation and self-control can predict better life outcomes. These children go on to have more educational and occupational success and to live longer, healthier lives.

Now a new study I helped lead has found another link between behavior in childhood and success later in life. The findings were published in the journal *JAMA Psychiatry*. My colleagues and I report that children who were rated as "inattentive" by kindergarten teachers had lower earnings at ages 33 to 35; those rated as prosocial—such as being kind, helpful and considerate—earned more.

This study shows that inattention may be among the most powerful early behavioral predictors of future earnings. It also demonstrates that it is possible to identify children at risk of lower future earnings based on a single teacher assessment made in kindergarten, which has important practical implications. If these children can be identified, then it may be possible to intervene—for example, by flagging them for further assessment or by providing support or prevention programs—and thus improve their life chances. An important strength of the paper is that it examined a range of specific childhood behaviors and controlled for the children's IQ and family background (such as their parents' education level and occupational status), something not all previous investigations have done.

The classic marshmallow study failed to account for intelligence and family background, which are known to influence future life success.

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Recent efforts to replicate that experiment using a larger and more diverse sample (the original one recruited children from Stanford University's campus nursery) found that the effect was roughly half of that seen in the classic study. When the researchers controlled for the children's IQ and family background, the effect virtually disappeared. In other words, the ability to delay gratification in childhood might matter for future success, but intelligence and family background matter much more.

In another influential study, published in 2011, children aged three to 11 with good self-control were reported to have more wealth, better health and fewer criminal conviction in early adulthood. But the paper failed to consider the role of antisocial traits, such as aggression and opposition. When these were adjusted for in a replication study, the effects were considerably weakened. One problem with self-control studies such as these is that they lump many traits—such as attention, delayed gratification and conscientiousness—

together to create a single composite self-control score, often combining traits assessed across multiple years. This approach makes it hard to identify the "active ingredients" that are linked with the outcome of interest, a crucial step if you plan to develop targeted intervention programs designed to improve life outcomes by promoting "good" traits and reducing "bad" ones.

Focusing on specific observable behaviors might lead to more reliable and useful predictors of future life outcomes. Experimental studies show that home- and school-based programs can reduce inattentive and disruptive behaviors and enhance prosocial traits through perspective-taking, relationship management, and social and emotional training. Also, they are readily observable and easy to measure in the classroom.

My and my colleagues' new study was based on analysis of nearly 3,000 children living in Canada, who were rated by teachers for behaviors, including inattention, hyperactivity, aggression, opposition, anxiety and prosocial traits, when they were in kindergarten. The children were then followed up for 30 years, and the behavioral ratings were linked to their tax-return records in adulthood. For boys and girls, ratings of inattention at age six were more strongly linked with lower future earnings than any other behavior. Furthermore, for boys only, ratings of aggression and opposition were linked with lower earnings, and prosocial behaviors were linked with higher earnings. The study accounted for other childhood behaviors, including hyperactivity and anxiety, which were not associated with earnings.

This study raises the question of what underlying factors might mediate—or explain—the association between childhood behavior and future life earnings. Low educational attainment and antisocial behavior may be particularly important.

Inattention in childhood is known to be linked with poor peer relations, substance abuse and antisocial behavior in adolescence, all of which can harm educational attainment and diminish employment opportunities, consequently lowering earnings. Similarly, childhood aggression and opposition are linked with substance dependence, antisocial behavior and criminal convictions, which could undermine educational and employment opportunities and lead to lower earnings. The association between boys' prosocial behaviors and higher earnings may be more intuitive: prosocial children typically get on better with their peers, have fewer behavioral problems in adolescence and perform better at school, which should enhance employment opportunities, collegial relations and, consequently, earnings.

The next step is to figure out which of these mediating pathways are most important in explaining the link between childhood behavior and poor economic outcomes in adulthood so they can be tested in intervention programs. Another important question, which wasn't addressed in our study, is why the behaviors associated with future earnings appear to differ for males and females. The answer may, in turn, suggest different interventions.

While the ability to wait for a couple of marshmallows may not predict life success, other traits do seem to matter. Where earnings are concerned, kindergartners' ability to pay attention—and boys' ability to be kind—appear particularly important. Fortunately, there are many good reasons to promote these traits.

—Francis Vergunst

Scientists Demonstrate Direct Brain-to-Brain Communication in Humans

Work on an "Internet of brains" takes another step

We humans have evolved a rich repertoire of communication, from gesture to sophisticated languages. All of these forms of communication link otherwise separate individuals in such a way that they can share and express their singular experiences and work together collaboratively. In a new study, technology replaces language as a means of communicating by directly linking the activity of human brains. Electrical activity from the brains of a pair of human subjects was transmitted to the brain of a third individual in the form of magnetic signals, which conveyed an instruction to perform a task in a particular manner. This study opens the door to extraordinary new means of human collaboration while, at the same time, blurring fundamental

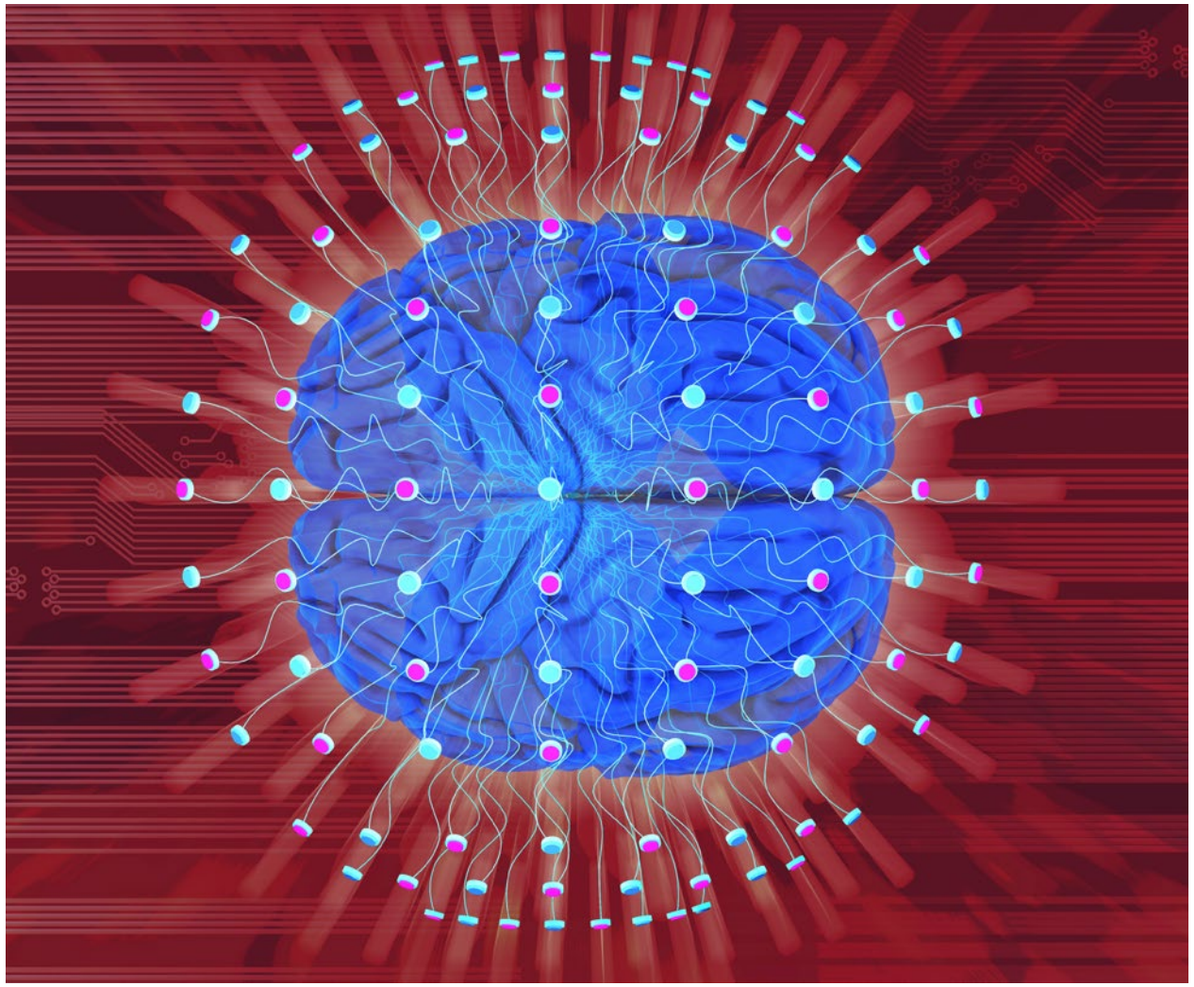
notions about individual identity and autonomy in disconcerting ways.

Direct brain-to-brain communication has been a subject of intense interest for many years, driven by motives as diverse as futurist enthusiasm and military exigency. In his book *Beyond Boundaries* one of the leaders in the field, Miguel Nicolelis, described the merging of human brain activity as the future of humanity, the next stage in our species' evolution. (Nicolelis serves on *Scientific American*'s board of advisers.) He has already conducted a study in which he linked together the brains of several rats using complex implanted electrodes known as brain-to-brain interfaces. Nicolelis and his co-authors described this achievement as the first "organic computer" with living brains tethered together as if they were so many microprocessors. The animals in this network learned to synchronize the electrical activity of their nerve cells to the same extent as those in a single brain. The networked brains were tested for things such as their ability to discriminate between two different patterns of electrical stimuli, and they routinely outperformed individual animals.

If networked rat brains are "smarter" than a single animal, imagine the capabilities of a biological supercomputer of networked human brains. Such a network could enable people to work across language barriers. It could provide those whose ability to communicate is impaired with a new means of doing so. Moreover, if the rat study is correct, networking human brains might enhance performance. Could such a network be a faster, more efficient and smarter way of working together?

The new paper addressed some of these questions by linking together the brain activity of a small network of humans. Three individuals sitting in separate rooms collaborated to correctly orient a block so that it could fill a gap between other blocks in a video game. Two individuals who acted as "senders" could see the gap and knew whether the block needed to be rotated to fit. The third individual, who served as the "receiver," was blinded to the correct answer and needed to rely on the instructions sent by the senders.

The two senders were equipped with electroencephalographs (EEGs) that recorded their brain's electrical activity. Senders were able to see the orientation of the block and decide whether to signal the receiver to rotate it. They focused on a light flashing at a high frequency to convey the instruction to rotate or focused on one flashing at a low frequency to signal not to do so. The differences in the flashing frequencies caused disparate brain responses in the senders, which were captured by the EEGs and sent, via computer interface, to the receiver. A magnetic pulse was delivered to the receiver using a transcranial magnetic stimulation (TMS) device if a sender signaled to rotate. That magnetic pulse caused a flash of light (a phosphene) in the receiver's visual field as a cue to turn the block. The absence of a signal within a



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discrete period of time was the instruction not to turn the block.

After gathering instructions from both senders, the receiver decided whether to rotate the block. Like the senders, the receiver was equipped with an EEG, in this case to signal that choice to the computer. Once the receiver decided on the orientation of the block, the game concluded, and the results were given to all three participants. This provided the senders with a chance to evaluate the receiver's actions and the receiver with a chance to assess the accuracy of each sender.

The team was then given a second chance to improve its performance. Overall, five groups of individuals were tested using this network, called the BrainNet, and, on average, they achieved greater than 80 percent accuracy in completing the task.

In order to escalate the challenge, investigators sometimes added noise to the signal sent by one of the senders. Faced with conflicting or ambiguous directions, the receivers quickly learned to identify and follow the instructions of the more accurate sender. This process emulated some of the features of "conventional" social networks, according to the report.

This study is a natural extension of work previously done in laboratory animals. In addition to the work linking together rat brains, Nicolelis's lab is responsible for linking multiple primate brains into a "Brainet" (not to be confused with the BrainNet discussed earlier), in which the primates learned to cooperate in the performance of a common task via brain-computer interfaces (BCIs). This time three primates were connected to the same computer with implanted BCIs and simultaneously tried to move a cursor to a target. The animals were not directly linked to each other in this case, and the challenge was for them to perform a feat of parallel processing, each directing its activity toward a goal while continuously compensating for the activity of the others.

Brain-to-brain interfaces also span across species, with humans using noninvasive methods similar to those in the BrainNet study to control cockroaches or rats that had surgically implanted brain interfaces. In one report, a human using a noninvasive brain interface linked, via computer, to the BCI of an anesthetized rat was able to move the animal's tail. While in another study, a human controlled a rat as a freely moving cyborg.

The investigators in the new paper point out that it is the first report in which the brains of multiple humans have been linked in a completely noninvasive manner. They claim that the number of individuals whose brains could be networked is essentially unlimited. Yet the information being conveyed is currently very simple: a yes-or-no binary instruction. Other than being a very complex way to play a Tetris-like video game, where could these efforts lead?

The authors propose that information transfer using noninvasive approaches could be improved by simultaneously imaging brain activity using functional magnetic resonance imaging (fMRI) in order to increase the information a sender could transmit. But fMRI is not a simple procedure, and it would expand the complexity of an already extraordinarily complex approach to sharing information. The researchers also propose that TMS could be delivered, in a focused manner, to specific brain regions in order to elicit awareness of particular semantic content in the receiver's brain.

Meanwhile the tools for more invasive—and perhaps more efficient—brain interfacing are developing rapidly. Elon Musk recently announced the development of a robotically implantable BCI containing 3,000 electrodes to provide extensive interaction between computers and nerve cells in the brain. While impressive in scope and sophistication, these efforts are dwarfed by government plans. The Defense Advanced Research Projects Agency (DARPA) has been leading engineering efforts to develop an implantable neural interface capable of engaging one million nerve cells simultaneously. While these BCIs are not being developed specifically for brain-to-brain interfacing, it is not difficult to imagine that they could be recruited for such purposes.

Even though the methods used here are noninvasive and therefore appear far less ominous than if a DARPA neural interface had been used, the technology still raises ethical concerns, particularly because the associated technologies are advancing so rapidly. For

example, could some future embodiment of a brain-to-brain network enable a sender to have a coercive effect on a receiver, altering the latter's sense of agency? Could a brain recording from a sender contain information that might someday be extracted and infringe on that person's privacy? Could these efforts, at some point, compromise an individual's sense of personhood?

This work takes us a step closer to the future Nicolelis imagined, in which, in the words of the late Nobel Prize–winning physicist Murray Gell-Mann, "thoughts and feelings would be completely shared with none of the selectivity or deception that language permits." In addition to being somewhat voyeuristic in this pursuit of complete openness, Nicolelis misses the point. One of the nuances of human language is that often what is not said is as important as what is. The content concealed in the privacy of one's mind is the core of individual autonomy. Whatever we stand to gain in collaboration or computing power by directly linking brains may come at the cost of things that are far more important.

—Robert Martone

Western Individualism Arose from Incest Taboo

Researchers link a Catholic Church ban on cousins marrying in the Middle Ages to the emergence of a way of life that made the West an outlier

ADRIAN GONZALEZ *GETTY IMAGES*

In what may come as a surprise to freethinkers and nonconformists happily defying social conventions these days in New York City, Paris, Sydney and other centers of Western culture, a new study traces the origins of contemporary individualism to the powerful influence of the Catholic Church in Europe more than 1,000 years ago, during the Middle Ages.

According to the researchers, strict church policies on marriage and family structure completely upended existing social norms and led to what they call "global psychological variation," major changes in behavior and thinking that transformed the very nature of the European populations.

The study, published last November in *Science*, combines anthropology, psychology and history to track the evolution of the West, as we know it, from its roots in "kin-based" societies. The antecedents consisted of clans, derived from networks of tightly interconnected ties, that cultivated conformity, obedience and in-group loyalty—while displaying less trust and fairness with strangers and discouraging independence and analytic thinking.

The engine of that evolution, the authors propose, was the church's obsession with incest and its determination to wipe out the marriages between cousins that those societies were built on. The result, the paper says, was the rise of "small, nuclear households, weak family ties, and

residential mobility," along with less conformity, more individuality, and, ultimately, a set of values and a psychological outlook that characterize the Western world. The impact of this change was clear: the longer a society's exposure to the church, the greater the effect.

Around A.D. 500, explains Joseph Henrich, chair of Harvard University's department of human evolutionary biology and senior author of the study, "the Western church, unlike other brands of Christianity and other religions, begins to implement this marriage and family program, which systematically breaks down these clans and kindreds of Europe into monogamous nuclear families. And we make the case that this then results in these psychological differences."

In their comparison of kin-based and church-influenced populations, Henrich and his colleagues identified significant differences in everything from the frequency of blood donations to the use of checks (instead of cash) and the results of classic psychology tests—such as the passenger's dilemma scenario, which elicits attitudes about telling a lie to help a friend. They even looked at the number of unpaid parking tickets accumulated by delegates to the United Nations.

"We really wanted to combine the kinds of measures that psychologists use, that give you some control in the lab, with real-world measures," Henrich says. "We really like the parking tickets. We get the U.N. diplomats from around the world all in New York City and see how they behave."

The policy has since changed, but for years diplomats who parked illegally were not required to pay the tickets the police wrote. In their analysis of those tickets, the researchers found that over the course of one year, diplomats from countries with higher levels of "kinship intensity"—the prevalence of clans and very tight families in a society—had many more unpaid parking tickets than those from countries without such history. Diplomats from Sweden and Canada, for example, had no outstanding tickets in the period studied, while unpaid parking tickets per diplomat were about 249 for Kuwait, 141 for Egypt and 126 for Chad. Henrich attributes this phenomenon to the insular mindset that is characteristic of intense kinship. While it builds a close and very cooperative group, that sense of cooperation does not carry beyond the group. "The idea is that you are less concerned about strangers, people you don't know, outsiders," he says.

The West itself is not uniform in kinship intensity. Working with cousin-marriage data from 92 provinces in Italy (derived from church records of requests for dispensations to allow the marriages), the researchers write, they found that "Italians from provinces with higher rates of cousin marriage take more loans from family and friends (instead of from banks), use fewer checks (preferring cash), and keep more of their wealth in cash instead of in banks, stocks, or other financial assets." They were also observed to make fewer voluntary, unpaid blood donations.

In the course of their research, Henrich and his colleagues created a database and calculated "the duration of exposure" to the Western church for every country in the world, as well as 440 "subnational European regions." They then tested their predictions about the influence of the church at three levels: globally, at the national scale; regionally, within European countries; and among the adult children of immigrants in Europe from countries with varying degrees of exposure to the church.

Henrich notes that the church's focus on marriage proscriptions rose to the level of obsession. "They came to the view that marrying and having sex with these relatives, even if they were cousins, was something like sibling incest in that it made God angry," he says. "And things like plagues were explained as a consequence of God's dissent."

The taboo against cousin marriage might have helped the church grow, adds Jonathan Schulz, an assistant professor of economics at George Mason University and first author of the paper. "For example," he says, "it is easier to convert people once you get rid of ancestral gods. And the way to get rid of ancestral gods is to get rid of their foundation: family organization along lineages and the tracing of ancestral descent."

The Western, educated, industrialized, rich and democratic (WEIRD) societies of Western Europe and what the authors call "their cultural descendants in North America and Australia" have long been recognized as outliers among the world's

populations for their independence of thought and other traits, such as a willingness to trust strangers.

The new paper is the first to systematically link that psychological variation to the Western church. "This study is truly novel and uniquely interdisciplinary," says Thomas Talhelm, an associate professor of behavioral science at the University of Chicago Booth School of Business, who was not involved with the work. "If we were to survey researchers in anthropology, cultural psychology, and evolution and ask them what explains Western WEIRD-ness, we would get all sorts of answers. And few would focus specifically on the church or the nuclear family."

As for the impact of the paper on those disciplines, Talhelm expects that some people will object to the sweeping nature of its conclusions. "Any time a theory of human culture scales up so big, there will be local exceptions and unique cases," he says. "Some researchers are deeply wary of generalizations, of large theories. Yet that wariness will overlook the usefulness of the theory and the consistency of the findings."

—David Noonan

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Deep Sleep Gives Your Brain a Deep Clean

Slow-wave activity during dreamless slumber helps wash out neural detritus

Why sleep has restorative—or damaging—effects on cognition and brain health has been an enduring mystery in biology. Researchers think cerebrospinal fluid (CSF) may flush toxic waste out, "cleaning" the brain, and studies have shown that garbage clearance is hugely improved during sleep. They were not sure exactly how all this works, however, or why it should be so enhanced during sleep.

One aspect of sleep that is well understood is how the slow electrical oscillations (or "slow waves") that characterize deep, non-REM sleep contribute to memory consolidation, the process whereby new memories are transferred into long-term storage. Now a study, from a team

led by neuroscientist Laura Lewis of Boston University, gives insight into what drives CSF flow through the brain, suggesting that the same slow waves that coordinate memory consolidation drive oscillations in blood flow and CSF in the brain.

The work has implications for understanding the relations between sleep disturbance and psychiatric and neurodegenerative conditions and may even point to new approaches to diagnosis and treatment. "We've discovered there are really large waves of CSF that appear in the brain only during sleep," Lewis says. "This effect is really striking, and we're also interested in what it means for maintaining brain health, especially in disorders such as Alzheimer's disease."

In the study, published on October 31, 2019, in *Science*, the team set out to investigate how the dynamics of CSF flow changes during sleep and how this might relate to alterations in brain blood flow and electrical activity. "We know sleep is really important for brain health, and waste clearance is probably a key reason why; what was less clear is: Why is this changed during sleep?" Lewis says. "That led us to ask what was happening in the CSF."

The researchers used electroencephalography (EEG) to monitor the brain waves of 13 sleeping healthy adults, while also using a cutting-edge, "accelerated" functional MRI technique to capture faster changes than standard fMRI can manage. That allowed for the measurement of both blood-oxygenation changes (which indicate blood flowing to electrically active, oxygen-hungry regions) and CSF flows. The latter was only possible because of a flaw in this method that means any newly arriving fluid (not just oxygenated blood) lights up in the image. "We realized we could take advantage of this to measure CSF flow at the same time as blood oxygenation," Lewis says. "That was critical because it turns out these things are coupled in a way we never would have seen if we didn't measure blood, CSF and electrical activity simultaneously."

What the team found was that the slow waves seen in non-REM sleep occur in lockstep with changes in both blood flow and CSF. Just because things occur together doesn't necessarily mean one causes the other, but the team also built a computer model

A Symphony in Two Movements

Dramatic differences characterize two key sleep phases. The slow waves of deep sleep dominate the early part of the night. During slow-wave sleep, some memories spontaneously reactivate. Interventions that promote this process can ensure that memories are retained. Rapid eye movement (REM) sleep prevails in the latter part of a night's slumber, but how it interacts with memory remains controversial.

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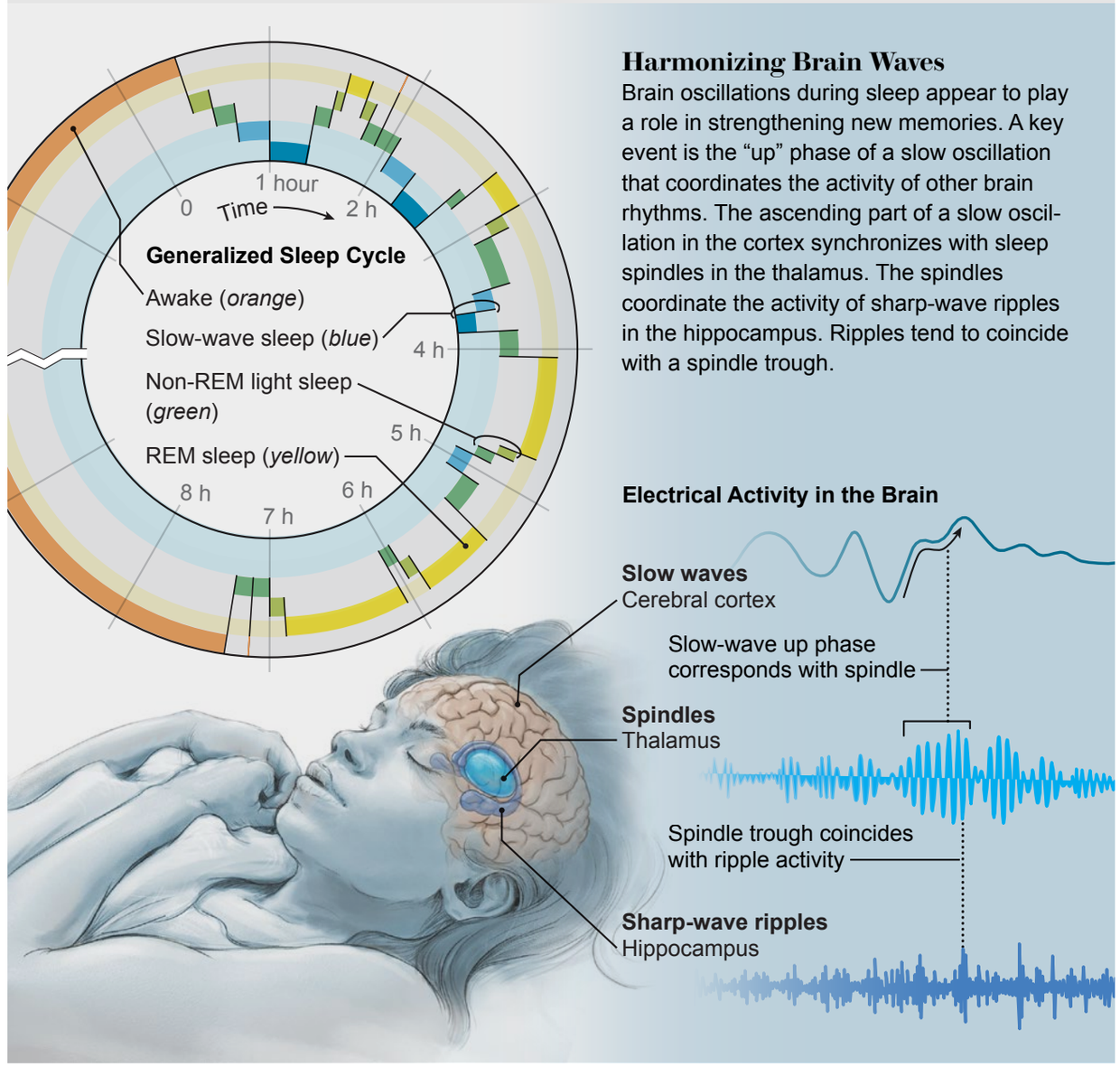

Harmonizing Brain Waves
Brain oscillations during sleep appear to play a role in strengthening new memories. A key event is the "up" phase of a slow oscillation that coordinates the activity of other brain rhythms. The ascending part of a slow oscillation in the cortex synchronizes with sleep spindles in the thalamus. The spindles coordinate the activity of sharp-wave ripples in the hippocampus. Ripples tend to coincide with a spindle trough.

MESA SCHUMACHER

incorporating what we know about the physics linking these processes, which predicted that slow waves would have just these kinds of effects on blood and CSF. What seems to be happening is that as brain activity alters blood flow, this reduces the volume of blood in the brain, and because the brain is a closed vessel, CSF flows in to fill the space. "It's very convincing," says neurologist Maiken Nedergaard of the University of Rochester, who was not involved with the research. "It also really makes sense: electrical activity drives blood flow changes, which then drive CSF changes."

The team measured this CSF inflow going into the fourth ventricle, one of four fluid-filled cavities involved in producing CSF (by filtering blood plasma) and circulating it around the brain. As CSF usually flows out of the fourth ventricle, this suggests a "pulsatile" flow, like a wave. This pushes CSF around the ventricles and into spaces between membranes surrounding the brain and spinal cord, called the meninges, where it mixes with "interstitial fluid" within the brain to carry away toxic waste products.

As slow waves are important for memory consolidation, this links two disparate functions of sleep. "What's exciting about this is it's combining features of brain function that people don't normally think of as connected," Nedergaard says. It isn't obvious things had to be this way, Lewis says, but it may represent an example of nature being efficient. "It's a matter of nature not dividing tasks between higher level and lower level, like how you run a company, where you have a boss making decisions and cleaning people coming in," Nedergaard says. "In biology, it's everybody contributing, as it makes more sense."

The findings have implications for neurodegenerative diseases, which are thought to be caused by build-up of toxic proteins in the brain, such as amyloid beta in Alzheimer's disease. Previous research has shown that amyloid beta is cleared more efficiently during sleep, which is often disrupted in patients. Disturbances in slow-wave sleep also often accompany aging, which may be linked to cognitive decline. "We know that people with Alzheimer's have fewer slow waves, so we may find they also have fewer CSF waves," Lewis says. "We have to do these studies now in older adults and patient populations, to understand what this might mean for those disorders." Sleep disturbance is also a feature of many psychiatric disorders, from depression to schizophrenia. "Different electrical signatures of sleep are disrupted in different psychiatric conditions," she says. "So this will be very interesting to follow up on in a multitude of disorders."

"What's exciting about this is it's combining features of brain function that people don't normally think of as connected."

—Maiken Nedergaard

The team next hopes to nail down whether electrical oscillations truly do cause the changes they observed in CSF flow, by experimentally manipulating brain activity. "It would be great to find the right collaborator and do a study in mice where we manipulate neural activity, then watch the downstream consequences," Lewis says. "We're also thinking about ways to safely and noninvasively manipulate neural oscillations in humans." It may ultimately be possible to use electromagnetic stimulation to influence brain waves as a treatment for brain disorders. Researchers have already seen encouraging results of this approach in mice, and these findings may help explain why. Another potential application may come from assessing whether changes in CSF flows can serve as a diagnostic marker for some of these conditions. "It gives us a ton of interesting new biology to explore and understand, since it seems like things the brain is doing during sleep are related to each other in surprising ways," Lewis says.

"Maybe the most important take-home message is that sleep is a serious thing," Nedergaard says. "You really need to sleep to keep a healthy brain because it links electrical activity to a practical housekeeping function."

—Simon Makin

Failure Found to Be an "Essential Prerequisite" for Success

Scientists use big data to understand what separates winners from losers

The recipe for succeeding in any given field is hardly a mystery: good ideas, hard work, discipline, imagination, perseverance and maybe a little luck. Oh, and let's not forget failure, which Dashun Wang and his colleagues at Northwestern University call "the essential prerequisite for success" in a new paper that, among other things, is based on an analysis of 776,721 grant applications submitted to the National Institutes of Health from 1985 to 2015.

In their effort to create a mathematical model that can reliably predict the success or failure of an undertaking, the researchers also analyzed 46 years' worth of venture capital start-up investments. They also tested the model on what Wang calls their "least conventional" but nevertheless important data set—170,350 terrorist attacks carried out between 1970 and 2017.

The takeaway? "Every winner begins as a loser," says Wang, associate professor of management and organizations at Northwestern's Kellogg School of Management, who conceived and led the study.

But not every failure leads to success, he adds. And what ultimately separates the winners from the losers, the research shows, certainly is not persistence. One of the more intriguing findings in the paper, published last October in *Nature,* is that the people who eventually succeeded and the people who eventually failed tried basically the same number of times to achieve their goals.

It turns out that trying again and again only works if you learn from your previous failures. The idea is to work smart, not hard. "You have to figure out what worked and what didn't and then focus on what needs to be improved instead of thrashing around and changing everything," Wang says. "The people who failed didn't necessarily work less [than those who succeeded]. They could actually have worked more; it's just that they made more unnecessary changes."

As they explored "the mechanisms governing the dynamics of failure" and built their model, Wang's team members identified what they describe as previously unknown statistical signatures that separate successful groups from nonsuccessful groups and make it possible to predict ultimate outcomes.

One such key indicator (besides keeping the stuff that works and focusing on what doesn't) is the time between consecutive failed attempts, which should decrease steadily. In other words, the faster you fail, the better your chances of success, and the more time between attempts, the more likely you are to fail again. "If

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someone has applied for a grant and they are three failures in," Wang says, "if we just look at the timing between the failures, we will be able to predict whether they will eventually succeed or not."

The massive National Institutes of Health database, which Wang calls a "graveyard full of human failures," turned out to be a researcher's dream come true. "For every principal investigator," Wang notes, "we know exactly when they failed, and we know how badly they failed because we know the scores of the proposal. And we also know when they eventually succeeded, after failing over and over, and got their first grant."

For the start-up domain, success was either an IPO or a high-value merger and acquisition. And for terrorism, attacks that killed at least one person were classified as successes; failures were attacks that did not claim casualties. The average number of failures for those who failed at least once before success was 2.03 for NIH, 1.5 for start-ups and 3.90 for terrorist groups.

Working with such large-scale data, Wang and his colleagues were able to identify a critical point common to each of the hundreds of thousands of undertakings they analyzed, a fork in the road where one path leads to a progression region and one leads to a stagnation region. As the paper explains, "two individuals near the critical point may initially appear identical in their learning strategy or other characteristics, yet depending on which region they inhabit, their outcomes following failures could differ dramatically."

This diverging pattern of performance increases with each new attempt, Wang says, although in some cases it is apparent which region a person is in as early as the second attempt.

Wang points out that the existence of the tipping point cuts against the traditional explanations for failure or success, such as luck or a person's work habits. "What we're showing here is that even in the absence of such differences, you can still have very different outcomes," he says. What matters is how people fail, how they respond to failure and where those failures lead. Looking ahead, Yian Yin, the first author of the study, says next steps include refining the model to quantify other individual and organizational characteristics besides learning from past failures.

Wang's model, tested now in three disparate domains, shows promise as a tool in other arenas, says Albert-László Barabási, director of the Center for Complex Network Research at Northeastern University and author of *The Formula: The Universal Laws of Success*. "There are countless works trying to understand how people and products succeed," he says. "There is very little understanding of the role of failure, however. Wang's work fundamentally rewrites our understanding of success, showing the key role failure plays in it, finally offering a methodological and conceptual framework to put failure where it belongs within the canon of success."

—David Noonan

Play May Be a Deeper Part of Human Nature Than We Thought

An animal study brings us closer to understanding our own behavior

by Ryan P. Dalton and Francisco Luongo

BAPTISTE FERNANDEZ *GETTY IMAGES*

Ryan P. Dalton is a neuroscientist, writer and former Miller Fellow at the University of California, Berkeley. His scientific work is centered on sensation and memory, and his writing focuses on minds, machines and the social impacts of biotechnology.

Francisco Luongo is a neuroscientist and Beckman Postdoctoral Fellow at the California Institute of Technology. His research concentrates on dissecting neural circuit mechanisms underlying object segmentation.

AS THE 61ST MINUTE OF the 2019 Women's World Cup Final between the U.S. and the Netherlands began, Megan Rapinoe stood at the edge of the penalty box, stoically awaiting the referee's whistle. An hour of attack and counterattack in the sweltering heat and under the anxious gaze of tens of thousands of fans had exhausted both sides but had yet to produce a goal for either. At the sound of the whistle, Rapinoe took a centering breath, trotted forward and skipped the ball into the back of the net, breaking the tie. As the stadium burst into exultation, Rapinoe headed for the sidelines; she had already taken 10 steps when her calm finally yielded to the unmistakable expression of pure joy. It was a beautiful moment and a reminder that while the spoils go to the winners, there are yet more powerful forces—in our biology, in our minds—that motivate us to play in the first place.

Playing is a universal human behavior and has therefore long been a subject of intense scientific interest. Nevertheless, because play is unprompted and natural—characteristics that do not usually lend themselves to laboratory work—much about its nature has remained mysterious. But in a thrilling study published recently in *Science*, experimenters concocted a work-around for this dilemma: they taught rats how to play a common childhood game. And in doing so, they made a series of discoveries suggesting that play is an even deeper part of our nature than previously thought.

How deep in our nature is play? It would be useful to begin by defining exactly what "play" is. Dutch historian and cultural theorist Johan Huizinga, in his now classic *Homo Ludens*, tried to do just that. Among other things, he argued that play must be voluntary: gladiatorial combat, in many cases, should be disqualified because its participants may have been forced into the arena. And play must occur in a space and time in which the rules are different from those in real life. Taking a time-out during a game is a way to leave that "magical circle."

Play also needs to be internally motivated and should carry no material interest—players may grow stronger or faster, but play should not feed, clothe or pay them. In that sense, most collegiate athletes—at least for now—are still playing. Most important of all, play should be fun. To formalize this notion, if play serves some behavioral or evolutionary function, then the neural circuits of the brain involved in motivation and reward should be active during its occurrence.

What is the function of play? In making that assessment, it helps to remember that humans are not the only ones that do it. According to *Homo Ludens*, play predates human culture. "Animals have not waited for man to teach them their playing," Huizinga wrote. He had a point: playing is a widespread behavior among animals, from dogs catching Frisbees to cats playing with, well, just about anything. Some types of play may involve learning to work cooperatively with a group for survival. Predators might engage in sparring or chasing games to simultaneously train and explore. Other types of play help animals learn how to follow complex rules, how to switch roles or even how to build a theory of mind. In general, games are critically important in establishing healthy social interactions, and failing to play them can result in inappropriate aggression, anxiety and social isolation.

Because of this role for playing in social learning, the most important games may be the ones we play when we are young. Take, for example, hide-and-seek—a game that has been passed down by oral tradition all over the world since ancient times. The fact that it is both ancient and widespread is an argument in favor of its importance. But hide-and-seek's roots may lie deeper yet: even rats can play it. And true to the definition of play, they seem to do it just because they like it.

In an attempt to understand the neuroscience of play, a group of scientists trained rats to play games of cross-species hide-and-seek. In each game, the human experimenter began by placing the rat in a small box. If the lid of the box was closed, the rat was the "seeker" and needed to "count off" in the box before setting out to find the experimenter, who had several objects to hide behind. If the lid of the box was left open, the rat was the "hider" and learned to quickly leave the box to find a hiding place before the experimenter began pursuit. In both scenarios, rats were rewarded only with social interaction.

During games when the rats were hiding, they preferred to be behind opaque rather than transparent objects, and they tended to stay very quiet until they were found—a commonsense strategy for those wishing to stay hidden—and basked in the accomplishment of besting a foe. On being found, rats often re-hid and awaited being discovered again, delaying their reward for playing. In contrast, during games when rats were seeking, they frequently vocalized and showed no preference for opaque versus transparent hiding places.

"Animals have not waited for man to teach them their playing."
—Johan Huizinga

Rats also showed evidence for memory-guided search strategies. In some trials, experimenters returned to the same hiding place over and over again. Rats were quick to catch on and tended to find the experimenters faster in later trials, suggesting conscious access to game history. Finally, by recording from the brains of rats while they played hide-and-seek, the experimenters identified a series of neurons in the prefrontal cortex—a brain region associated with abstract coding of reward, motivation and rules—whose activities were correlated with specific phases of the game. Together these results indicate that rats can learn the rules of hide-and-seek and that these rules have corresponding signatures in the their brains. In other words, hide-and-seek may be evolutionarily ancient.

These findings come as quite a surprise, which, in the world of research, means they have opened several new avenues of study. One primary reason for surprise is the complexity of the game the rats were playing. In a statistical sense, hide-and-seek could be thought of as a game of location inference. To be a good hider or seeker is to predict where the other individual will be hiding or looking and to exploit any prior knowledge ("Remy always hides in the chef's hat"). Indeed, the rats showed evidence for such behavior by returning to previously used locations, suggesting this paradigm could be leveraged to understand how we make inferences about the actions and intentions of others. Knowing rats can play hide-and-seek should therefore motivate us to ask what the boundaries on game complexity are for different animals—and whether, by seeking out those boundaries, we might better understand animal intelligence.

Another reason these findings are surprising has more to do with our understanding of what could still be hiding in the human mind. As Huizinga might have said, play is freedom. By acknowledging that nonhuman animals can exercise a type of freedom that seems very human, this research may chip away at the idea of certain human freedoms as exceptional. As scary as that sounds, it moves us closer to understanding ourselves, which is the ultimate goal of neuroscience.

But perhaps the greatest surprise in this story comes from the boldness in how it was told. Scientific research often relies on strict experimental protocols, controls and constraints. There is a reason for this practice: by minimizing variability, experimenters can build high-confidence predictions about specific processes. But just as there are benefits to studying the unusual, there are benefits to studying the ordinary in unusual ways. By examining an act of freedom, this study has taught us much about being free. In doing so, it has attempted to corner an age-old question: Why do we play? The answer may have less to do with fame, glory, money or power than with Rapinoe's rapturous smile as she jogged free of the penalty box last July: we play because it is in our nature to do so.

How Dishonesty Drains You

Deceitful behavior diminishes our ability to read emotions, with many consequences

By Julia Lee, Ashley Hardin, Bidhan Parmar and Francesca Gino

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HAVE YOU EVER TOLD A FRIEND A MADE-UP STORY TO ENTERTAIN that person or spare his or her feelings? Do you know anyone who confessed to you he or she overreported the number of hours worked to pad a paycheck? Some may think of these "white lies," or small instances of dishonest behavior, as relatively harmless or a slight ethical lapse, when compared with full-scale corporate fraud. We may consider a white lie to be especially harmless if it is in service of protecting an important relationship. Researchers have studied the potential financial and legal consequences of such small instances of dishonesty as padding expense reports and pilfering pens. But are these consequences all that we should be concerned about? We examined the possibility that small instances of dishonest behavior have unintended consequences for our emotional intelligence—it seeps into our ability to read others' emotions. Our research indicates the harm is real—and lasting.

In a series of studies, we concluded that an act of deceit can undermine a person's ability to interact with peers, even those removed from the original lie. Specifically, we found that when people engage in dishonest behavior, they are less likely to see themselves as relational (for example, as a sister, friend, colleague or father) and are subsequently less accurate in judging the emotions of others. This investigation is a critical step in understanding the underlying interpersonal dynamics in organizations, specifically, because work relationships can be generative—a source of enrichment and vitality—or corrosive—a source of pain and dysfunction. The ability to accurately read and respond to others' emotional states enables supportive, prosocial and compassionate behaviors, so it is particularly important for building strong networks in professional settings. Because of an increase in relational distance and a decrease in empathic accuracy, those who are dishonest at work may experience a vicious cycle of mutual misunderstandings and missed opportunities for building supporting relationships, which could be detrimental for individuals, as well as for the organizations in which they work.

We began to explore these dynamics in a study of 250 pairs of individuals, comprised of a participant in an experimental condition—asked to lie or tell the truth—and a partner, with each tasked to assess the emotions of the other. We found that subjects who lied, as compared with the truth tellers, were less accurate in judging the emotions of their partner. Those in the dishonest group were not instructed to tell large lies; instead they were to make up a story about looking for a job—something that would amuse others or make them feel better about their own experiences with recruiting. The other half of the experimental participants were asked to tell a story based on their real experiences as job seekers.

After sharing these stories, all of those individuals listened to their partner tell a real story and then rated the emotions they felt. After sharing stories with each other,

participants and partners reported their own emotions, as well as the emotions they sensed their counterpart was feeling. We used the reported emotions to calculate an accuracy score for a participant's view of his or her partner's emotions (the difference between the partner's reported emotions and the participant's report of that partner's emotions). We found that subjects who were asked to be dishonest were significantly worse at accurately detecting the emotional state of their partner than those who told a true story. Surprisingly, these small, malice-free moments of dishonesty significantly clouded an individual's ability to read emotions in subsequent interactions.

In conjunction with this investigation, we ran four additional experimental studies with two conditions: In one, we created specific circumstances where participants would be tempted to cheat. And in the other, we removed any possibility of cheating. All subjects took part in a die-throwing game that allowed them to earn a bonus, based on the number rolled: the higher the number, the more money earned. While all participants were asked to choose if their bonus would be based on the top or bottom side of each die before rolling it, only those in the honest group did so at that time. Those in the dishonest group recorded their selection after the roll, which allowed them to change it to the side corresponding to the maximum amount of money they could earn. They reported earning significantly more over the course of the game, suggesting they did indeed inflate their bonus payments dishonestly. After the die-rolling activity, the subjects watched 42 short video clips to assess their ability to read the emotions of others. In these clips, actors expressed a wide range of emotions in their face, voice and body language, and participants were asked to identify the affective state of the actors.

Across these four experimental studies, with 1,879 participants, we consistently found that those who were tempted and likely lied ended up performing worse on the empathic accuracy test than those who did not have an opportunity to be dishonest. We also found that the effect was driven by a reduction in how relational dishonest participants considered themselves. People that engaged in dishonesty were less likely to describe themselves in terms of their relationships than those in the honest group. By being dishonest, subjects distanced themselves from others, which led to a reduced ability to read others' emotions.

By being dishonest, subjects distanced themselves from others, which led to a reduced ability to read others' emotions.

We ran an additional study to examine if the relationship between dishonesty and impaired empathic accuracy can be seen outside the laboratory. In it, 250 full-time employees reported how frequently they engaged in dishonest behavior (for example, "There are times when I violate contract terms with customers"). These participants then engaged in a common test of empathic accuracy, the Reading the Mind in the Eyes Test, which was developed by Simon Baron-Cohen of the University of Cambridge and his colleagues. In this experiment, across 36 trials, participants viewed the eyes of an actor and were asked which emotion best described his or her mental state. We found that the more frequently employees committed dishonest behavior at work, the lower they scored in empathic accuracy, suggesting the two are negatively related.

There was one feature that inoculated individuals from this negative effect of dishonesty: In a lab study of 100 adults, we found that those who had a naturally high level of social sensitivity—attunement to subtle social-emotional cues in the environment—did not show significant reductions in their empathic abilities following moments of dishonesty. But for the average participant across our studies, the negative effect was detected.

More, important, we found that a reduction in empathic accuracy as a result of dishonesty can have downstream consequences: specifically, participants who cheated for a financial gain were more likely to blatantly dehumanize the actors who appeared in these videos (that is, they rated the actors as less human) than those who did not have the opportunity to cheat. Moreover, cheaters were also more likely to engage in repeated unethical behavior. This result suggests that once we engage in dishonest behavior, we may also distance ourselves from other people by regarding them as less human, which allows us to continue down a path of subsequent, repeated unethical behavior. Our research implies that even small acts of dishonesty can go a long way, leaving ripple effects that may undermine a fundamental building block of our humanity: social connection.

Cultivating Emotion Regulation and Mental Health

Susanne Schweizer is a neuroscientist investigating the development of emotional regulatory processes and their role in mental health across the life span

By Scott Barry Kaufman

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The ability to regulate our emotions is essential to reaching our goals and feeling mentally healthy. Since this is such an important topic, I was delighted to get a chance to interview Susanne Schweizer, a Sir Henry Wellcome fellow at the University College London Institute of Cognitive Neuroscience. Schweizer studies the role of cognitive processes (for example, emotion regulation) and their neural substrates in the development and maintenance of common mental health problems across the life span, with a particular focus on adolescence. Adopting a translational perspective, Schweizer applies insights from basic developmental cognitive neuroscience to design novel interventions for mental health problems, including depression and post-traumatic stress disorder. Before moving to U.C.L., she completed her Ph.D. as a Gates Scholar and later postdoc at the University of Cambridge.

Susanne Schweizer

How did you become interested in emotion regulation?

My interest was sparked a decade ago. I spent a summer working with the late Nolen-Hoeksema in the department of psychology at Yale University. Part of my job was to read about emotion regulation. What I was struck by then was the pervasiveness of emotion regulation difficulties across different types of mental health problems, from depression to eating disorders. This sense was brought home the following spring, which I spent completing my clinical internship on an acute closed psychiatric ward. It didn't seem to matter what the disorder was—every form of psychopathology appeared to be accompanied by a breakdown in the ability to regulate emotions and mood. This was fascinating to me, and I needed to understand what was causing these problems in emotion regulation. So I went to do a Ph.D. with one of the world's foremost experts on mood and emotions in mental health, Tim Dalgleish at the University of Cambridge's MRC Cognition and Brain Sciences Unit.

What can the brain tell you about emotion regulation?

Just a couple of years before I started my Ph.D., James Gross of Stanford University and Kevin Ochsner of New York University developed their influential neuroscientific account of emotion regulation. Their model proposed that successful emotion regulation relies on cognitive control. Cognitive control refers to our ability to attend to information that is relevant to our goals, while ignoring distracting information. Their reason for suggesting this was accumulating evidence from brain-imaging studies, which showed that the brain regions that are recruited during cognitive control overlapped with the brain regions involved in emotion regulation. This was particularly interesting to me because we know that this cognitive-control capacity is reduced in individuals who suffer from mental health problems.

The question "How does our cognitive- control capacity interact with our affective experiences?" became the focus of my work. Dalgleish and I showed that when people's ability to exert cognitive control in emotional contexts improved by training with basic computerized tasks, their ability to regulate their emotions also improved. Not only did participants report becoming better able to downregulate their distress to aversive films after our training but there were also changes in their brains. Specifically, the improved emotion regulation ability following the training was associated with changes in activation of the ventrolateral prefrontal cortex. Previous work had shown that this brain region is critical to deploying cognitive control in affective contexts. Our initial work was carried out with healthy individuals, but since then we have taken the training to clinical populations, including post-traumatic stress disorder, and showed similar benefits in emotion regulation. Based on this work I became interested in whether we could prevent emotion-regulation difficulties from appearing in the

first place, but to do this I needed to understand how emotion regulation develops.

How does emotion regulation develop across the life span?

There is robust evidence that emotion regulation rapidly improves during early childhood. Less is known, however, about its development in adolescence and beyond. To explore this, I joined world-renowned developmental cognitive neuroscientist Sarah-Jayne Blakemore and her research group, who study adolescent development at University College London's Institute of Cognitive Neuroscience. Together we have been looking at age-related differences in the cognitive building blocks that underlie successful emotion regulation. That is, we study how adolescents and adults differ in their ability to exert cognitive control in emotional compared with neutral contexts. To study this, we ask individuals to do cognitively demanding tasks, such as remembering numbers that are presented one after another in working memory. To manipulate emotional context, we present these numbers over neutral or emotional background images. We found that the impact of emotional information on performance is associated with adolescents' mental health, particularly in early adolescence (11 to 14 years). This means, the more difficulty adolescents have performing working memory tasks in emotional relative to neutral contexts, the more mental health difficulties they experience at an early age.

Yet these cross-sectional studies don't tell us anything about development of emotion-regulation ability across time. For example, we don't know whether these underlying abilities remain stable within an individual or improve with age. Or whether they fluctuate from day to day or even moment to moment. To study this, we have developed a citizen science app—the Emotional Brain Study app.

How do you study emotion regulation with a citizen science app, and what is citizen science?

The idea behind citizen science is that science and science policy are made open and accessible to the public. Citizen science ensures that science remains responsive to society's concerns and needs and acknowledges that anyone in society can themselves produce reliable scientific knowledge. In the case of our app, we ask the general public to help us study emotion-regulation development and its association with mood across the life span. By providing us with very basic information about themselves and playing games on the app, individuals who use the app become "citizen scientists." Within the app they first record their current mood as well as what they are doing that moment in time, and they then play any one of five games. These games tap into the cognitive functions that underlie successful emotion regulation. Specifically, they test memory, attention and other complex cognitive functions in the context of emotional and neutral information. The scientific data this citizen science project creates will allow us to start modeling how the cognitive control of emotions develops across the life span and how it might fluctuate within individuals. This is invaluable information that will improve our understanding of the basic cognitive functions underlying successful emotion regulation and, by extension, good mental health.

What can app-based research tell us that lab-based research can't?

From our lab-based work we know that individuals who suffer from or who are at risk for mental health problems find playing these games harder in emotional compared with neutral contexts. We know very little, however, about how these functions relate to everyday mood and moment-to-moment mood fluctuations. Gathering larger-scale data on the association between performance on these games and mood using our app will allow us to explore these relationships and detect potential avenues for intervention. That means we will be able to optimize our training protocols to improve emotion regulation, hopefully before people even start experiencing mental health problems related to poor emotion regulation.

How will this research help those who struggle with emotion regulation or even mental health problems?

Imagine a scenario where regular digital mental health and cognition check-ups become commonplace. Symptoms can be recorded on apps, and the types of games included in our app can be played to measure changes in cognitive functioning. Changes can indicate cognitive improvement or decline. Adding an affective dimension to the games, we may find that they can also help us discover when our abilities to regulate our emotions may be optimal or, on the contrary, start to become impaired. We can start tracking what improves or reduces our emotion-regulation capacity. But for these games to realize their prognostic potential, we need to ensure they are reliable markers of emotion regulation, and data from our Emotional Brain Study app will help us do exactly that. The more people use our app regularly, the more data we will have, and the finer-grained the data modeling and validation we will be able to do when exploring the association between cognition, emotion regulation and mood across the life span. These are new frontiers for mental health researchers who study mental health from a developmental cognitive neuroscience perspective. Results from these new avenues of research will hopefully bring much needed improvements to our existing means of preventing and treating mental health problems.

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OBSERVATIONS

A New Way to Think about Mental Illness

Instead of looking for "the" cause of schizophrenia, depression and other disorders, we should consider whether there might be a network of causes

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Have you ever heard of a condition known as "general paresis of the insane"? Probably not. In the 19th century general paresis was one of the most commonly diagnosed mental disorders. Its symptoms included odd social behaviors, impaired judgment, depressed mood and difficulty concentrating. Around the turn of the 20th century, though, we figured what it really was—a form of late-stage syphilis infecting the brain and disrupting its function. A few decades later we discovered a highly effective treatment: penicillin.

Although general paresis is now very rare, its example is still instructive. Any honest researcher will tell you we don't currently have good explanations for most mental disorders. Depression, obsessive-compulsive disorder, schizophrenia—we don't really know how these patterns of disrupted thought, behavior and emotion develop or why they stick around.

Yet the hope remains that, much like with general paresis, we may soon discover the root causes of these illnesses, and this knowledge may tell us how to treat them. An example of this hope can be seen in the popular notion that a "chemical imbalance" causes depression. This might turn out to be true, but the truth is that we don't know.

Some researchers are starting to think that for many mental disorders, such hope might be based

on incorrect assumptions. Instead of having one root cause, as general paresis did, mental disorders might be caused by many mechanisms acting together. These mechanisms might be situated in the brain, but they could also be located in the body and even in the external environment, interacting with one another in a network to create the patterns of distress and dysfunction we currently recognize and label as varieties of mental illness. In this more complex view, patterns such as depression and generalized anxiety arise as tendencies in the human brain-body-environment system. Once the patterns are established, they are hard to change because the network continues to maintain them.

If the causal structures of many mental disorders are complex, how should we seek to illuminate them? I think that recognizing the complexity should push us to rethink how mental illness is studied.

For a start, we should no longer be looking for just one nugget of truth. Rather than a moment of discovery—Alexander Fleming noticing that a mold seemed lethal to bacteria or Archimedes leaping from his bath yelling, "Eureka!"—we should expect a more gradual process of knowledge gathering. Instead of one paradigm-defining discovery, coming to understand mental disorders will probably be much more like a team of paleontologists slowly brushing away dirt to reveal a set of fossils and developing ideas about how all the bones fit together to form a complete dinosaur.

Instead of a single theory—the X theory of depression—we will likely need multiple explanations that each focus on different mechanisms in the network. As hypothetical examples, theories might emerge at a neurological level showing how difficulty experiencing pleasure relates to difficulty sleeping and at a psychological and ecological level explaining how changes that depressed people make to their environments contribute to the perpetuation of their mood (the latter example is inspired by this paper).

In the paper this essay is loosely based on, which will be published in the journal *Theory & Psychology*, my Ph.D. supervisor and I propose a structure to help researchers organize the process of discovery. We call it relational analysis of phenomena, or RAP. In RAP, researchers break down disorders into meaningful parts and richly describe these parts at multiple scales of analysis: What is going on in people's brains and bodies? How does it feel? What do they do? How does it change their environment? How do others react to it?

Only after this rigorous description process does the investigator try to explain the relationship between some of the parts. The overarching intention is to slowly uncover the mechanisms of the disorder in people's lives. Once we understand enough of the causes at play, we may begin to understand how the dysfunctional pattern of behavior is maintained and how best to effect positive change.

Ultimately some mental disorders might turn out to be like general paresis, with one well-defined cause in the brain. Others might turn out to be distortions in thought, behavior and emotion supported by a network of mechanisms. Most disorders are probably somewhere in the middle, with one or more dominant causes and a plethora of less dominant ones. Because we don't really know, investing in multiple explanatory strategies seems the optimal way forward. The alternative—assuming that mental disorders are all brain disorders—places all our eggs in one basket.

We must develop effective treatments for mental disorders as rapidly as possible. But to do so, we first need to be able to explain what is going on. Assuming from the get-go that brain dysfunction is always the cause is like shooting ourselves in the foot before we even start the race.

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BEAUTIFUL MINDS

Galileo's Big Mistake

How the great experimentalist created the problem of consciousness

Galileo shows the Doge his telescope, 1609.

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If a tree falls in a forest and there's no one there to see it, does it make a sound? An age-old philosophical conundrum you might think; in fact, this question was given a definitive answer in the 17th century by the father of modern science, Galileo Galilei. And the way in which Galileo answered this question shaped the philosophical foundations of the scientific worldview that remains with us to this day. Moreover, as I will explain, this scientific worldview has a big problem at its heart: it makes a science of consciousness impossible.

A key moment in the scientific revolution was Galileo's declaration that mathematics was to be the language of the new science; the new science was to have a purely quantitative vocabulary. This is a much discussed moment. What is less discussed is the philosophical work Galileo had to do to get to this position. Before Galileo, people thought the physical world was filled with qualities: there were colors on the surfaces of objects, tastes in food, smells floating through the air. The trouble is that you can't capture these kinds of qualities in the purely quantitative vocabulary of mathematics. You can't capture the spicy taste of paprika, for example, in an equation.

This presented a challenge for Galileo's aspiration to exhaustively describe the physical world in mathematics. Galileo's solution was to propose a

radically new philosophical theory of reality. According to this theory, the qualities aren't really out there in the world; instead they're in the consciousness of the observer. The redness of the tomato isn't really on the surface of the tomato but is rather in the consciousness of the person perceiving it; the spiciness of the paprika isn't really in the paprika but in the consciousness of the person consuming it. To return to the example we began with, when a tree comes crashing down in a forest, the crashing sound isn't really in the forest but in the consciousness of an onlooker. No onlooker, no consciousness, no sound.

Galileo, as it were, stripped the physical world of its qualities. And after he'd done that, all that remained were the purely quantitative properties of matter—size, shape, location, motion—properties that can be captured in mathematical geometry. In Galileo's worldview, there is a radical division between the following two things:

- The physical world with its purely quantitative properties, which is the domain of science,
- Consciousness, with its qualities, which is outside of the domain of science.

It was this fundamental division that allowed for the possibility of mathematical physics: once the qualities had been removed, all that remained of the physical world could be captured in mathematics. And hence, natural science, for Galileo, was never intended to give us a complete description of reality. The whole project was premised on setting qualitative consciousness outside of the domain of science.

What do these 17th-century discussions have to do with the contemporary science of consciousness? It is now broadly agreed that consciousness poses a very serious challenge for contemporary science. Despite rapid progress in our understanding of the brain, we still have no explanation of how complex electrochemical signaling could give rise to a subjective inner world of colors, sounds, smells and tastes.

Although this problem is taken very seriously, many assume that the way to deal with this challenge is simply to continue with our standard methods for investigating the brain. The great success of physical science in explaining more and more of our universe ought to give us confidence, it is thought, that physical science will one day crack the puzzle of consciousness.

This common approach is, in my view, rooted in a profound misunderstanding of the history of science. We rightly celebrate the success of physical science, but it has been successful precisely because it was designed, by Galileo, to exclude consciousness. If Galileo were to time travel to the present day and hear about this problem of explaining consciousness in the terms of physical science, he'd say, "Of course, you can't do that! I designed physical science to deal with quantities, not qualities." And the fact that physical science has done incredibly well when it excludes consciousness gives us no grounds for thinking it will do just as well when it turns to explaining consciousness itself.

This is not to say that physical science has no role to play in the science of consciousness. Neuroscientists have made great progress in mapping correlations between brain activity on the one hand and conscious experience on the other. Giulio Tononi's integrated information theory of consciousness, to take a prominent example, proposes that consciousness is correlated with maximal integrated information, a notion for which the theory gives a precise mathematical characterization. But mere correlations are not a theory of consciousness.

What we ultimately want is a way of explaining these correlations that neuroscientists uncover. Why is it that maximal integrated information, a quantitative property, always goes along with consciousness, a qualitative phenomenon? The problem is that our adoption of Galileo's view of the physical world blocks us from answering this question. Consciousness is essentially defined by the qualities—colors, sounds, smells, tastes—that characterize every second of waking life.

And those qualities, by definition, cannot be incorporated in a purely quantitative picture of the physical world. The Galilean understanding of the physical world as purely quantitative bars us from bringing together the qualitative and the quantitative in a single, unified picture of reality. The best we can do is to map correlations.

Pessimists will infer from these considerations that we will never have a science of consciousness, that consciousness will always be something magical and mysterious. That's not my approach. I think we can have confidence that we will one day have a science of consciousness, but we need to rethink what science is. The science of Galileo was not designed to deal with

consciousness. If we now want a science of consciousness, we need to move to a more expansive "post-Galilean" conception of the scientific method, one that takes seriously both the quantitative properties of matter than we know about through observation and experiment and the qualitative reality of consciousness that each of us knows through our immediate awareness of our feelings and experiences.

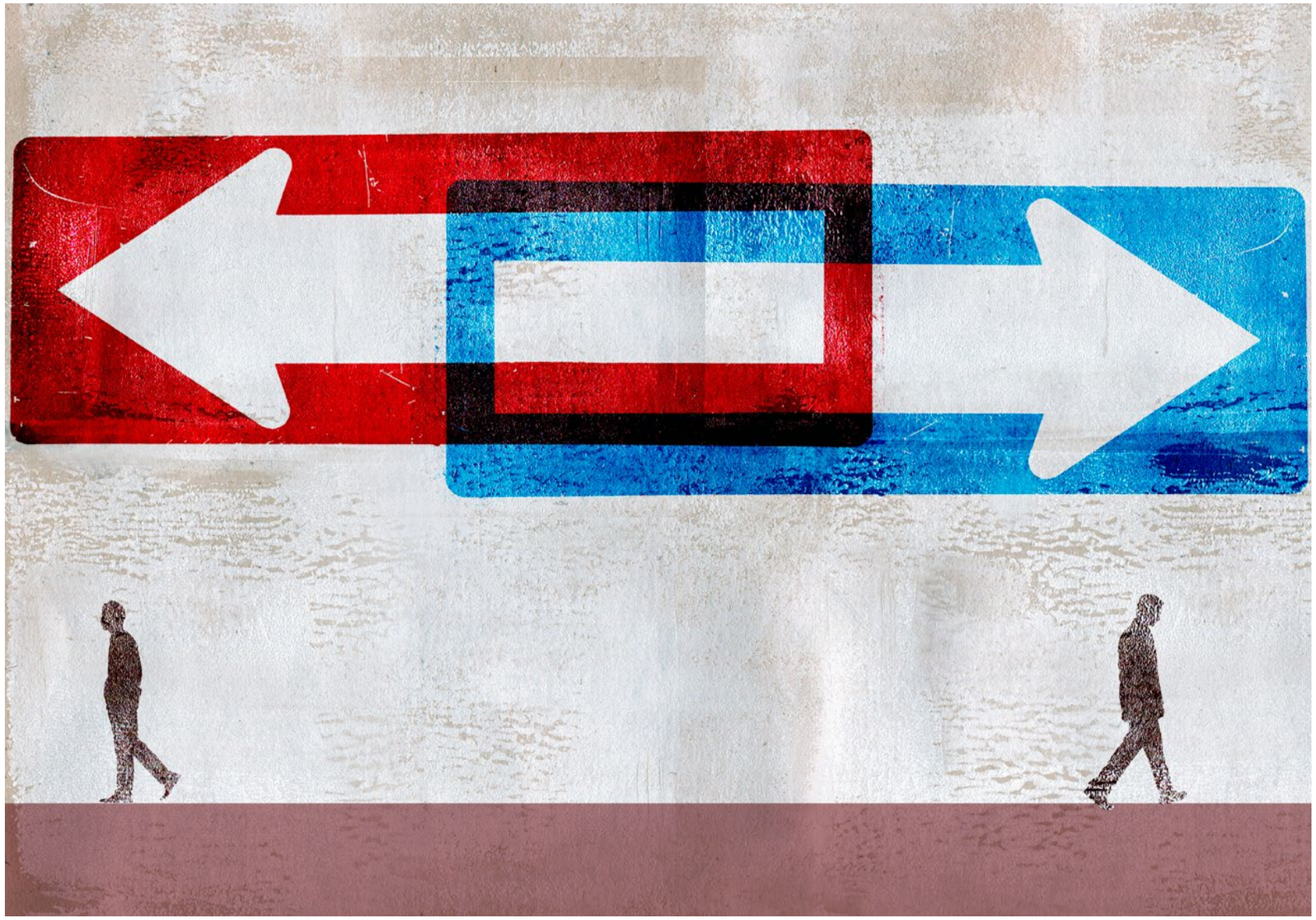
Nothing short of a revolution is called for, and it's already on its way. As I describe in my new book *Galileo's Error: Foundations for a New Science of Consciousness*, scientists and philosophers have begun to come together to lay the groundwork for a new approach to consciousness. And this matters. The change in worldview that is called for cannot help but have profound implications for society more generally. Consciousness is at the root of human identity; indeed, it is arguably the basis of everything of value in human existence. This new scientific revolution will transform not only our understanding of the physical universe but also of what it means to be a human being.

Scott Barry Kaufman is a psychologist at Columbia University exploring intelligence, creativity, personality and well-being. In addition to writing the column Beautiful Minds for *Scientific American,* he hosts The Psychology Podcast and is author and/or editor of eight books, including *Wired to Create: Unravelling the Mysteries of the Creative Mind* (with Carolyn Gregoire) and *Ungifted: Intelligence Redefined.* Find out more at http://ScottBarryKaufman.com

COGNITION

Can Empathic Concern Actually Increase Political Polarization?

Research suggests that those who display the most concern for others are also the most socially polarized



ROY SCOTT GETTY IMAGES

Imagine you're walking home late at night, and you see a poor, defenseless man being being bullied and called horrible names. Things start to escalate, and the crowd starts pushing him around, knocking off his hat and screaming at him more loudly. The man looks scared and calls out to you for help. Think about how you feel.

Now imagine that as you get closer, you see a MAGA hat on the ground lying right next to the guy. It's clear that the crowd had thrown his hat on the ground as they continue to taunt him and make fun of him for being a Trump supporter. Does that change how you feel?

Partisan politics in the U.S. is increasingly becoming a matter of "us" versus "them." While the issues themselves haven't necessarily become more polarized, our identities have become more tied to our politics. This has resulted in "a nation that agrees on many things but is bitterly divided nonetheless."

One recent survey found that among those who are highly engaged in politics, 70 percent of Democrats and 62 percent of Republicans say they are "afraid" of the other party, and a near majority of Democrats and Republicans report being angry with the opposing party and see the opposing party as a threat to the nation's well-being.

Barack Obama has proposed that a major

source of this political conflict is an "empathy gap." But what if the reality is far more complex, and empathy in certain circumstances is actually the problem?

Empathy Gone Awry

While empathy consists of multiple overlapping processes, perhaps the facet most closely related to everyday conceptions of empathy is empathic concern. In the psychological literature, empathic concern refers to the tendency to experience sympathy or compassion for another person who is in distress. The empathic concern scale includes items such as "I often have tender concerned feelings for people less fortunate than me" and "When I see someone being taken advantage of, I feel kind of protective toward them."

While empathic concern is often assumed to be a universal good, there are many cases in which empathy does not live up to its promise. Even those who score high on psychological tests of empathy aren't always empathic.* After all, empathy is hard work. As a result, people often choose to avoid empathy, viewing it as just not worth the effort.

One important factor is the nature of the relationship with another person. Research shows that the suffering of a perceived member of an outgroup dampens the empathic response compared with empathic concern for an in-group member's suffering.

Consider a study in which soccer fans witnessed a fan of their favorite team (in-group member) or a rival team (out-group member) experience pain. Participants were then able to choose to help the fan by enduring physical pain themselves to reduce the other's pain. People reported greater empathic concern for another's pain and were more willing to personally endure pain to reduce another's pain when that person was an in-group member rather than an out-group member.

Additionally, helping the in-group member was predicted by activation of the anterior insula area of the brain, whereas not helping the out-group member was associated with activation of the nucleus accumbens area of the brain. The researchers conclude that empathy-related insula activation can motivate costly helping, whereas an antagonistic signal in the nucleus accumbens reduces the urge to help another person in need.

Empathic Concern and Political Polarization

What about within the realm of politics? Are we all just treating politics as though it were one big sports game? In this extremely partisan climate, it certainly seems so. As political psychologist Lilliana Mason put it, "a partisan behaves more like a sports fan than like a banker choosing an investment. Partisans feel emotionally connected to the welfare of the party; they prefer to spend time with other members of the party; and when the party is threatened, they become angry and work to help conquer the threat, even if they disagree with some of the issue positions taken by the party."

In a new paper, political psychologist Elizabeth Simas and her colleagues get to the bottom of this contentious issue. Across two studies, they demonstrated that the experience of empathic concern is biased toward one's group and can actually exacerbate political polarization.

In one study based on surveys taken from a nationally representative sample, they found that as empathic concern increases, individuals are more likely to be biased toward their own party and are more likely to show increased hostility toward the out-group. The effect was particularly pronounced among partisans and was much weaker among "leaners" and independents.†

In another study, people were randomly assigned to receive one of two versions of a short article describing a recent protest on a college campus. In both versions, campus police had to shut down a group of partisan students who were protesting a speech to be given by a person known for making inflammatory comments about that party. In both versions, a bystander who was attempting to hear the speech was struck by a protestor. And in both versions, the protestors succeeded in getting the speech canceled. The researchers only varied the partisan implications. In one condition, the speaker criticized Democrats and was protested by the college Democrats; in the other condition, the speaker criticized Republicans and was protested by the college Republicans.

They found that those at the higher end of empathic concern were significantly more likely to want to stop the speech when the speaker was from the opposite party. Those at the higher end of empathic concern were even more likely to show schadenfreude for the injured student when the speaker was from the opposite party, being more likely to find it funny and amusing

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that the student was injured. So much for empathic concern!

The researchers conclude: "The evidence we present implies that the real-world effects of empathy are not as positive as they are often assumed to be."

What's the Solution?

It might be tempting to look at these studies and conclude that the problem is with empathy itself. We should all just become Spocks and rationally compute the utilitarian value of political policies regardless of political party or the suffering of any particular group of individuals. While I'm sure there will be those who are all for that alternative, I would argue that this would be a very misguided conclusion. After all, I've written before how it's our antagonism with one another—not our empathy—that is ripping America (and the world) apart. The story is definitely more complex.

For one, Elizabeth Simas and her colleagues did find a big upside to empathic concern: Whereas empathic concern increased dislike of the out-party, it increased comfort with out-party contact. Those high in empathic concern were less likely to be upset by the prospect of having a family member or neighbor who belongs to the opposite party. Therefore, empathic concern does have an approach-oriented aspect to it that encourages contact with out-party members, even if the primary goal of that contact is to alter behavior that is seen as harmful to one's in-group.

Second, even when excluding controls for empathic concern and other aspects of empathy, perspective-taking did not significantly reduce partisan bias. This may seem counterintuitive to some people, who might think that increasing perspective-taking might increase mutual understanding, but the results point out that even that doesn't offer a simple solution. As developmental psychologist Paul Bloom has rightly pointed out, even "cognitive empathy" (which includes perspective-taking) "is overrated as a force for good," considering that the ability to take the perspective of another person can be used for cruelty and exploitation of others.

So what should we conclude? All else equal, I do believe that scoring high in dispositional empathic concern is a good thing. Research shows that citizens higher in empathic concern are more motivated to participate in the political process in order to reduce harm. Those high in empathic concern are also more likely to be attracted to the more prosocial aspects of running for and holding political office.

I think the findings of Simas and her colleagues are a reflection of the particular political landscape which we find ourselves in. With the rise of Trump exacerbating long-standing hostilities, people are finding the need to hitch their entire existence on a political identity more so than ever and are getting stuck in their online echo chambers to a degree perhaps unprecedented in American history.

Therefore, in our current political climate, in which we have so much more shared experiences with in-group members than out-group members, it may indeed be possible that those predisposed toward empathic responding are more likely to have hostility toward their partisan "opponents" and may even enjoy their suffering. As empathy researcher Jamil Zaki has shown, empathy is very contextual and is affected strongly by motivation. Particularly when resources are limited or intergroup conflict is featured so predominantly on news outlets, empathy can be costly.

What we need is a stronger motivation for out-group empathic care. The best way for that to happen, in my view, is not by decreasing one's general disposition toward caring for the suffering of others but by increasing one's contact with members of the out-group and focusing on common experiences and concerns that we all share. The good news is that those with higher levels of empathic concern are more likely to to be comfortable with

contact with members of the opposite party.

But that's only a start. Simply reporting that one is high in empathic concern—either through a psychological test or on social media—is simply not enough, especially when we are ideologically blinded to see the suffering of those whose political views are different than ours. The only way out of this mess is to not treat political affiliation as a zero-sum game. That requires seeking out stories of suffering from as many different walks of life as possible.

I remain optimistic that we can get past this but only if we can broaden our spotlight of empathic concern to extend to as many members of the human race as humanly possible.

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*Vice versa, those who score low on psychological tests of empathic empathy aren't always callous. I've been thinking a lot about this, and it does seem that if you look really closely at the lives of those who we often treat as "monsters" or "evil," you see that they actually did show quite a bit of empathy toward members of their perceived in-group (albeit in some cases that in-group may have been indeed quite a small circle).

† Even though there was a positive relation between empathic concern and liberalism, they found no evidence of an interaction between empathic concern and partisan identity. Interestingly, while empathic concern was correlated with the more general personality traits of agreeableness and openness to experience, none of their conclusions changed after controlling for those broader dimensions of personality.

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

OPINION

A Pair of Crocs to Match the Dress

Casting new light on viral illusions

In 2015 the picture of a white-and-gold dress (or was it black-and-blue?) divided humankind in two irreconcilable factions while revolutionizing scientists' understanding of color perception. It was a brand-new category of illusion, in which different people perceived the same image in diametrically opposing ways. The two sections were locked in their respective perceptions. Try as they might, neither blue/black nor white/gold adherents could make themselves see the garment as the other side did.

Similarly baffling Internet sensations followed: a dresser that people saw as either white/pink or blue/gray, a sneaker that looked pink/white or green/gray to different observers, and an Adidas jacket that was either blue/white or brown/black depending on whom you asked.

Despite their differences, a common feature of these described images is that they were flukes, revealed by happenstance. The serendipity of their discoveries raised the question of wheth-

PASCAL WALLISCH

er scientists had a true understanding of how the newfound illusions might come about.

Pascal Wallisch, a neuroscientist at New York University, believes that the key to the puzzle is observers' previous knowledge of lighting sources and materials such as fabrics—what psychology researchers call "priors." To prove it, Wallisch and his New York University collaborator Michael Karlovich devised a method of creating color illusions that are just as confounding as those previously found by chance. The Crocs and socks photograph at the beginning of this article is one example. To create the image, Wallisch and Karlovich started with an object that looks pink under white light (a pair of "Ballerina Pink Classic Crocs") and instead illuminated it with green light, equalizing its appearance to gray. Then, they made the background pitch-black, removing any contextual color cues that the visual system might utilize. As a result, the Crocs might be any color or at least any of the 28 different hues that you might find at your favorite Crocs retailer.

Depending on your past familiarity with white tube socks (your prior), your visual system may correctly conclude that the socks are truly white but illuminated by green lighting. If so, you may be able to retrieve the Crocs' original pink color in your perception. Observers who lack the white sock prior may instead perceive the Crocs as grayish.

People believe that they see things "how they really are," Wallisch says. "But does this mean the colors of the pixels in isolation or of the whole shoe in context? Those two [interpretations] can be different for different people."

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