SPECIAL COLLECTOR'S EDITION

SCIENTIFIC AMERICAN MIND

BEHAVIOR • BRAIN SCIENCE • INSIGHTS

KEYS TO SUCCESSFUL LEARNING

DIGITAL DEVICES: GOOD OR BAD?

AUTISM INTERVENTIONS THAT WORK

STRESS BUSTERS FOR CHILDREN

TOP 10 PARENTING TECHNIQUES

HOW THE TEEN BRAIN THINKS

RAISE GREAT KIDS!

HOW TO HELP THEM THRIVE IN SCHOOL AND LIFE

SCIENTIFIC AMERICAN
MIND™
BEHAVIOR • BRAIN SCIENCE • INSIGHTS

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COVER PHOTOGRAPH AND THIS PAGE: ALAMY

SECRETS OF SUCCESSFUL PARENTING

Amazon offers more than 180,000 parenting guides—more than double the number of diet books, as psychology professor Robert Epstein notes in "What Makes a Good Parent" (*page 58*). Clearly, many parents long for child-rearing advice. The articles in this issue offer a host of insights grounded solidly in scientific research.

The findings might surprise you. Academic testing, for instance, has a terrible rap these days. Yet done correctly, it beats other study methods for fixing information in a student's mind (*page 38*). Moreover, telling children that they are smart can backfire; if you want them to be eager learners and creative thinkers, praising effort is far more effective (*page 10*).

Beyond wanting our children to love learning, we hope that they will get along well with others, be happy and bounce back from adversity. More time for unstructured play may be part of what is needed. This activity has been linked to improved social development; it also enhances cognition and language skills (*page 50*). And go to page 58 for 10 scientifically validated steps parents can take to raise happy, well-adjusted kids.

Teens may seem like aliens, and their brains *are* different from those of both adults and younger kids. Neuroscience reveals that the recklessness of the teen years is the product of a brain that has a newfound taste for exploration but underdeveloped impulse control. Although this makes teens seem frighteningly rebellious, it also means that their brains are capable of great creativity and adaptability (*page 92*). Other unexpected positive news: peer pressure can work for good as well as ill; it can actually induce older kids to learn faster from both positive and negative experiences and improve their performance on school tasks (*page 110*).

This collection also speaks to parents facing unusually taxing situations. For children with intense anxiety and fear, for instance, investigators have shown that techniques enabling youngsters to gradually face worries head-on can do wonders (*page 76*). Articles also tackle divorce (*page 90*) and defiance (*page 64*) and discuss therapies that have proved helpful to children on the autism spectrum (*page 70*).

Epstein reports that you will already be moving in the right direction if you follow this simple guidance: give your kids lots of love and affection. The pages that follow tell you the rest of what you need to know.

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RAISE GREAT KIDS

SPECIAL COLLECTOR'S EDITION

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Articles in this special issue are updated from previous issues of *Scientific American* and *Scientific American Mind*.

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RAISE GREAT KIDS

Even the youngest children know, experience and learn far more than scientists ever thought possible

Photographs by **Timothy Archibald**

HOW BABIES THINK

By **Alison Gopnik**

Thirty years ago most psychologists, philosophers and psychiatrists thought that babies and young children were irrational, egocentric and amoral. They believed children were locked in the concrete here and now—unable to understand cause and effect, imagine the experiences of other people, or appreciate the difference between reality and fantasy. People still often think of children as defective adults.

But in the past three decades scientists have discovered that even the youngest children know more than we would ever have thought possible. Moreover, studies suggest that children learn about the world in much the same way that scientists do—by conducting experiments, analyzing statistics, and forming intuitive theories of the physical, biological and psychological realms. Since about 2000, researchers have started to understand the underlying computational, evolutionary and neurological mechanisms that underpin these remarkable early abilities. These revolutionary findings not only change our ideas about babies, they give us a fresh perspective on human nature itself.

PHYSICS FOR BABIES

Why were we so wrong about babies for so long? If you look cursorily at children who are four years old and younger (the age range I will discuss in this article), you might indeed conclude that not much is going on. Babies, after all, cannot talk. And even preschoolers are not good at reporting what they think. Ask your average three-year-old an open-ended question, and you are likely to get a beautiful but incomprehensible stream-of-consciousness monologue. Earlier researchers, such as the pioneering Swiss psychologist Jean Piaget, concluded that children's thought itself was irrational and illogical, egocentric and "precausal"—with no concept of cause and effect.

The new science that began in the late 1970s depends on techniques that look at what babies and young children do instead of just what they say. Babies look longer at novel or unexpected events than

at more predictable ones, and experimenters can use this behavior to figure out what babies expect to happen. The strongest results, however, come from studies that observe actions as well: Which objects do babies reach for or crawl to? How do babies and young children imitate the actions of people around them?

Although very young children have a hard time telling us what they think, we can use language in more subtle ways to tease out what they know. For example, Henry Wellman of the University of Michigan has analyzed recordings of children's spontaneous conversations for clues to their thinking. We can give children very focused questions—for instance, asking them to choose between just two alternatives rather than asking an open-ended question.

In the mid-1980s and through the 1990s, scientists using these techniques discovered that babies already know a great deal about the world around them. That knowledge goes well beyond concrete, here-and-now sensations. Researchers such as Renee Baillargeon of the University of Illinois and Elizabeth S. Spelke of Harvard University found that infants understand fundamental physical relations such as movement trajectories, gravity and containment. They look longer at a toy car appearing to pass through a solid wall than at events that fit basic principles of everyday physics.

By the time they are three or four, children have elementary ideas about biology and a first understanding of growth, inheritance and illness. This early biological understanding reveals that children go beyond superficial perceptual appearances when they reason about objects. Susan A. Gelman, also at Michigan, found that young children believe that animals and plants have an "essence"—an invisible core that stays the same even if outside appearances change.

For babies and young children, the most important knowledge of all is knowledge of other people. Andrew N. Meltzoff of the University of Washington showed that newborns already understand that people are special and will imitate their facial expressions.

In 1996 Betty Repacholi (now at the University of Washington) and I found that 18-month-olds can understand that I might want one thing, whereas you want another. An experimenter showed 14- and 18-month-olds a bowl of raw broccoli and a bowl of goldfish crackers and then tasted some of each, making either a disgusted face or a happy face. Then she put her hand out and asked, "Could you give me some?" The 18-month-olds gave her broccoli when she acted as if she liked it, even though they would not choose it for themselves. (The 14-month-olds always gave her crackers.) So even at this very young age, children are not completely egocentric—they can take the perspective of another person, at least in a simple way. By age four, their understanding of everyday psychology is even more refined. They can explain, for instance, if someone is acting oddly because he or she believes something that is not true.

By the end of the 20th century experiments had thus charted impressively abstract and sophisticated knowledge in babies and the equally impressive growth of that knowledge as children get older. Some scientists have argued that babies must be born knowing much of what adults know about how objects and people behave. Undoubtedly, newborns are far from being blank slates, but the changes in children's knowledge also suggest that they are learning about the world from their experiences.

One of the greatest mysteries of psychology and philosophy is how human beings learn about the world from a confusing mess of sensory data. Over the past decade researchers have begun to understand much more about how babies and young children can learn so much so quickly and accurately. In particular, we have discovered that babies and young children have an extraordinary ability to learn from statistical patterns.

Babies look longer at novel or unexpected events than at more predictable ones, and experimenters can use this behavior to figure out what babies expect to happen.

THE STATISTICS OF BLICKETS

In 1996 Jenny R. Saffran, Richard N. Aslin and Elissa L. Newport, all then at the University of Rochester, first demonstrated this ability in studies of the sound patterns of language. They played sequences of syllables with statistical regularities to some eight-month-old babies. For example, "ro" might follow "bi" only one third of the time, whereas "da" might always follow "bi." Then they played the babies new strings of sounds that either followed these patterns or broke them. Ba-

FAST FACTS
BABY BRAINS

1. Babies' and young children's cognitive abilities far surpass those that psychologists long attributed to them. They can, for instance, imagine another person's experiences and grasp cause and effect.
2. Children learn about the world much as scientists do—in effect, conducting experiments, analyzing statistics and forming theories to account for their observations.
3. The long helplessness of babies may be an evolutionary trade-off, a necessary consequence of having brains wired for prodigious feats of learning and creativity.

bies listened longer to the statistically unusual strings. More recent studies show that babies can detect statistical patterns of musical tones and visual scenes, as well as more abstract grammatical patterns.

Babies can even understand the relation between a statistical sample and a population. In a 2008 study my University of California, Berkeley, colleague Fei Xu showed eight-month-old babies a box full of mixed-up Ping-Pong balls: say, 80 percent white and 20 percent red. The experimenter would then take out five balls, seemingly at random. The babies were more surprised (that is, they looked longer and more intently at the scene) when Xu pulled four red balls and one white one out of the box—an improbable outcome—than when she pulled out four white balls and one red one.

Detecting statistical patterns is just the first step in scientific discovery. Even more impressively, children (like scientists) use those statistics to draw conclusions about the world. In a version of the Ping-Pong ball study with 20-month-old babies using toy green frogs and yellow ducks, the experimenter would take five toys from the box and then ask the child to give her a toy from some that were on the table. The children showed no preference between the colors if the experimenter had taken mostly green frogs from the box of mostly green toys. Yet they specifically gave her a duck if she had taken mostly ducks from the box—apparently the children thought her statistically unlikely selection meant that she was not acting randomly and that she must prefer ducks.

In my laboratory we have been investigating how young children use statistical evidence and experimentation to figure out cause and effect, and we find their thinking is far from being "precausal." We introduce them to a device we call "the blicket detector," a machine that lights up and plays music when you put some things on it but not others. Then we can give children patterns of evidence about the detector and see what causal conclusions they draw. Which objects are the blickets?

In 2007 Tamar Kushnir, now at Cornell University, and I found that preschoolers can use probabilities to learn how the machine works. We repeatedly put one of two blocks on the machine. The machine lit up two out of three times with the yellow block but only two out of six times for the blue one. Then we gave the children the blocks and asked them to light up the machine. These children, who could not yet add or subtract, were more likely to put the high-probability yellow block on the machine. (More recently, Anna Waismeyer of the University of Washington and I discovered that even 24-month-olds could do this.)

Statistician at Work Babies are skillful statistical analysts. Experiments showed that eight-month-olds notice if an improbable number of red Ping-Pong balls are taken out of a collection that is mostly white. Variations of the experiments (such as swapping the role of red and white) control against alternative explanations (such as having a greater interest in red objects). Twenty-month-olds tested with green and yellow toys inferred that a person taking an unusually large number of the rare color would prefer to be given a toy of that color. Thus, babies and young children learn about the world like scientists—by detecting statistical patterns and drawing conclusions from them.

They still chose correctly when we waved the high-probability block over the machine, activating it without touching it. Although they thought this kind of "action at a distance" was unlikely at the start of the experiment (we asked them), these children could use probability to discover brand-new and surprising facts about the world.

In another experiment Laura Schulz, now at the Massachusetts Institute of Technology, and I showed four-year-olds a toy with a switch and two gears, one blue and one yellow, on top. The gears turn when you flip the switch. This simple toy can work in many ways. Perhaps the switch makes both gears turn at once, or perhaps the switch turns the yellow gear, which turns the blue one, and so on. We showed the children pictures illustrating each of these possibilities—the yellow gear would be depicted pushing the blue one, for instance. Then we showed them toys that worked in one or the other of these ways and gave them rather complex evidence about how each toy worked. For example, the children who got the "causal chain toy" saw that if you removed the blue gear and turned the switch, the yellow gear would still turn but that if you removed the yellow gear and turned the switch, nothing happened.

We asked the children to pick the picture that matched how the toy worked. Four-year-olds were amazingly good at ascertaining how the toy worked based on the pattern of evidence that we presented to them. Moreover, when other children were just left alone with the ma-

THE AUTHOR

ALISON GOPNIK is professor of psychology and affiliate professor of philosophy at the University of California, Berkeley. She has done groundbreaking research into how children develop a "theory of mind," the ability to understand that other people have minds and may believe or want different things than they do. She helped to formulate the "theory theory," the idea that children learn in the same way that scientists do. Investigations of children's minds, she argues, could help us resolve deep philosophical questions such as the mystery of consciousness.

chine, they played with the gears in ways that helped them learn how it worked—as if they were experimenting.

Another study by Schulz used a toy that had two levers and a duck and a puppet that popped up. One group of preschoolers was shown that the duck appeared when you pressed one lever and that the puppet popped up when you pressed the other one. The second group saw that when you pressed both levers at once, both toys popped up, but they never got a chance to see what the levers did separately. Then the experimenter had the children play with the toy. Children from the first group played with the toy much less than those from the second group. They already knew how it worked and were less interested in exploring it. The second group faced a mystery, and they spontaneously played with the toy, soon uncovering which lever did what.

These studies suggested that when children play spontaneously ("getting into everything") they are also exploring cause and effect and doing experiments—the most effective way to discover how the world works.

THE BABY COMPUTER

Obviously children are not doing experiments or analyzing statistics in the self-conscious way that adult scientists do. The children's brains, however, must be unconsciously processing information in a way that parallels the methods of scientific discovery. The central idea of cognitive science is that the brain is a kind of computer designed by evolution and programmed by experience.

Computer scientists and philosophers have begun to use mathematical ideas about probability to understand the powerful learning abilities of scientists—and children. A whole new approach to developing computer programs for machine learning uses what are called probabilistic models, also known as Bayesian models or Bayes nets. The programs can unravel complex gene expression problems or help understand climate change. The approach has also led to new ideas about how the computers in children's heads might work.

Probabilistic models combine two basic ideas. First, they use mathematics to describe the hypotheses that children might have about things, people or words. For example, we can represent a child's causal knowledge as a map of the causal relations between events. An arrow could point from "press blue lever" to "duck pops up" to represent that hypothesis.

Second, the programs systematically relate the hypotheses to the probability of different patterns of events—the kind of patterns that emerge from experimentation and statistical analysis in science. Hypotheses that better fit the data become more likely. I have argued that children's brains may relate hypotheses about the world to patterns of probability in a similar way. Children reason in complex and subtle ways that cannot be explained by simple associations or rules.

Furthermore, when children unconsciously use this Bayesian statistical analysis, they may actually be better than adults at considering unusual possibilities. In a study published in 2014 in *Cognition,* my colleagues and I showed four-year-olds and adults a blicket detector that worked in an odd way, requiring two blocks on it together to make it go. The four-year-olds were better than the adults at grasping this unusual causal structure. The adults seemed to rely more on their prior knowledge that things usually do not work that way, even though the evidence implied otherwise for the machine in front of them.

In other recent research my group found that young children who think they are being instructed modify their statistical analysis and may become less creative as a result. The experimenter showed four-year-olds a toy that would play music if you performed the right sequence of actions on it, such as pulling a handle and then squeezing a bulb. For some children, the experimenter said, "I don't know how this toy works—let's figure it out." She proceeded to try out various longer-action sequences for the children, some that ended with the short sequence and made music and some that did not. When she asked the children to make the toy work, many of them tried the correct short sequence, astutely omitting actions that were probably superfluous based on the statistics of what they had seen.

With other children, the experimenter said that she would teach them how the toy worked by showing them sequences that did and did not produce

Natural Experimenters

Four-year-olds are adept at interpreting evidence to learn about cause and effect, such as determining if one cog on a machine is turning another (*opposite page*). Some even carried out the correct experiments (and drew the right conclusion) while freely "playing" with the toy. Research involving a "blicket detector" (*below*), which is more likely to light up for some combinations of blocks than for others, found that four-year-olds could use statistics to learn how the machine worked, even when it showed new, unexpected behavior. Indeed, they were more open-minded than adults when faced with evidence that the machine responded to blocks in an unusual way.

music, and then she acted on the toy in exactly the same way. When asked to make the toy work, these children never tried a shortcut. Instead they mimicked the entire sequence of actions. Were these children ignoring the statistics of what they saw? Perhaps not—their behavior is accurately described by a Bayesian model in which the "teacher" is expected to choose the most instructive sequences. In simple terms: if she knew shorter sequences worked, she would not have shown them the unnecessary actions.

EVOLUTION AND NEUROLOGY

If the brain is a computer designed by evolution, we can also ask about the evolutionary justification and neurological basis for the extraordinary learning abilities we see in very young children. Recent biological thinking is in close accord with what we see in the psychology lab.

From an evolutionary perspective, one of the most striking things about human beings is our long period of immaturity. We have a much longer childhood than any other species. Why make babies so helpless for so long and thus require adults to put so much work and care into keeping their babies alive?

Across the animal kingdom, the intelligence and flexibility of adults are correlated with the immaturity of babies. "Precocial" species such as chickens rely on highly specific innate capacities adapted to one particular environmental niche, and so they mature quickly. "Altricial" species (those whose offspring need care and feeding by parents) rely on learning instead. Crows, for instance, can take a new object, such as a piece of wire, and work out how to turn it into a tool, but young crows depend on their parents for much longer than chickens.

A learning strategy has many advantages, but until learning takes place, you are helpless. Evolution solves this problem with a division of labor between babies and adults. Babies get a protected time to learn about their environment, without having to actually do anything. When they grow up, they can use what they have learned to be better at surviving and reproducing—and taking care of the next generation. Fundamentally, babies are designed to learn.

Neuroscientists have started to understand some of the brain mechanisms that allow all this learning to occur. Baby brains are more flexible than adult brains. They have far more connections between neurons, none of them particularly efficient, but over time they prune out unused connections and strengthen useful ones. Baby brains also have a high level of the chemicals that make brains change connections easily.

The brain region called the prefrontal cortex is distinctive to humans and takes an especially long time to mature. The adult capacities for focus, planning and efficient action that are governed by this brain area depend on the long learning that occurs in childhood. This area's wiring may not be complete until the mid-20s.

The lack of prefrontal control in young children naturally seems like a huge handicap, but it may actually be tremendously helpful for learning. The prefrontal area inhibits irrelevant thoughts or actions. But being uninhibited may help babies and young children to explore freely. There is a trade-off between the ability to explore creatively and learn flexibly, like a child, and the ability to plan and act effectively, like an adult. The very qualities needed to act efficiently—such as swift automatic processing and a highly pruned brain network—may be intrinsically antithetical to the qualities that are useful for learning, such as flexibility.

A new picture of childhood and human nature emerges from the research of the past decade. Far from being mere unfinished adults, babies and young children are exquisitely designed by evolution to change and create, to learn and explore. Those capacities, so intrinsic to what it means to be human, appear in their purest forms in the earliest years of our lives. Our most valuable human accomplishments are possible because we were once helpless dependent children and not in spite of it. Childhood, and caregiving, is fundamental to our humanity. M

MORE TO EXPLORE

- **The Scientist in the Crib: Minds, Brains, and How Children Learn.** Alison Gopnik, Andrew N. Meltzoff and Patricia K. Kuhl. William Morrow and Company, 1999.
- **The Philosophical Baby: What Children's Minds Tell Us about Truth, Love, and the Meaning of Life.** Alison Gopnik. Farrar, Straus and Giroux, 2009.
- **When Younger Learners Can Be Better (or at Least More Open-Minded) Than Older Ones.** A. Gopnik, T. L. Griffiths and C. G. Lucas in *Current Directions in Psychological Science,* Vol. 24, No. 2, pages 87–92; April 2015.
- **The Gardener and the Carpenter: What the New Science of Child Development Tells Us about the Relationship between Parents and Children.** Alison Gopnik. Farrar, Straus and Giroux (in press).

THE SECRET TO RAISING SMART KIDS

RAISE GREAT KIDS

By
Carol S. Dweck

D S

Hint: Don't tell your kids that they are. More than three decades of research shows that a focus on "process"—not on intelligence or ability—is key to success in school and in life

A brilliant student, Jonathan sailed through grade school. He completed his assignments easily and routinely earned As. Jonathan puzzled over why some of his classmates struggled, and

his parents told him he had a special gift. In the seventh grade, however, Jonathan suddenly lost interest in school, refusing to do homework or study for tests. As a consequence, his grades plummeted. His parents tried to boost their son's confidence by assuring him that he was very smart. But their attempts failed to motivate Jonathan (who is a composite drawn from several children). Schoolwork, their son maintained, was boring and pointless.

Our society worships talent, and many people assume that possessing superior intelligence or ability—along with confidence in that ability—is a recipe for success. More than 35 years of scientific investigation suggest, however, that an overemphasis on intellect or talent leaves people vulnerable to failure, fearful of challenges and unwilling to remedy their shortcomings.

The result plays out in children like Jonathan, who coast through the early grades under the dangerous notion that no-effort academic achievement defines them as smart or gifted. Such children hold an implicit belief that intelligence is innate and fixed, making striving to learn seem far less important than being (or looking) smart. This belief also makes them see challenges, mistakes and even the need to exert effort as threats to their ego rather than as opportunities to improve. And it causes them to lose confidence and motivation when the work is no longer easy for them.

Praising children's innate abilities, as Jonathan's parents did, reinforces this mind-set, which can also prevent young athletes or people in the workforce and even marriages from living up to their potential. On the other hand, our studies show that teaching people to have a "growth mind-set," which encourages a focus on "process" (consisting of personal effort and effective strategies) rather than on intelligence or talent, helps make them into high achievers in school and in life.

THE OPPORTUNITY OF DEFEAT

I first began to investigate the underpinnings of human motivation—and how people persevere after setbacks—as a psychology graduate student at Yale University in the 1960s. Animal experiments by psychologists Martin Seligman, Steven Maier and Richard Solomon, all then at the University of Pennsylvania, had shown that after repeated failures, most animals conclude that a situation is hopeless and beyond their control. After such an experience, the researchers found, an animal often remains passive even when it can effect change—a state they called learned helplessness.

People can learn to be helpless, too, but not everyone reacts to setbacks this way. I wondered: Why do some students give up when they encounter difficulty, whereas others who are no more skilled continue to strive and learn? One answer, I soon discovered, lay in people's beliefs about *why* they had failed.

In particular, attributing poor performance to a lack of ability depresses motivation more than does the belief that lack of effort or poor strategies are to blame. In 1972, when I taught a group of elementary and middle school children who displayed helpless behavior in school that a lack of effort (rather than lack of ability) led to their mistakes on math problems, the kids learned to keep trying when the problems got tough. They also solved many more problems even in the face of difficulty. Another group of helpless children who were simply rewarded for their success on easier problems did not improve their ability to solve hard math problems. These experiments were an early indication that a focus on effort can help resolve helplessness and engender success.

Subsequent studies revealed that the most persistent students do not ruminate about their own failure much at all but instead think of mistakes as problems to be solved. At the University of Illinois in the 1970s I, along with my then graduate student Carol Diener, asked 60 fifth graders to think out loud while they solved very difficult pattern-recognition problems. Some students reacted defensively to mistakes, denigrating their skills with comments such as "I never did have a good rememory [*sic*]," and their problem-solving strategies deteriorated.

FAST FACTS

GROWING PAINS

1. Many people assume that superior intelligence or ability is a key to success. But more than three decades of research shows that an overemphasis on intellect or talent—and the implication that such traits are innate and fixed—leaves people vulnerable to failure, fearful of challenges and unmotivated to learn.
2. Teaching people to have a "growth mind-set," which encourages a focus on "process" rather than on intelligence or talent, produces high achievers in school and in life.
3. Parents and teachers can engender a growth mind-set in children by praising them for their persistence or strategies (rather than for their intelligence), by telling success stories that emphasize hard work and love of learning, and by teaching them how the brain gets stronger as we learn.

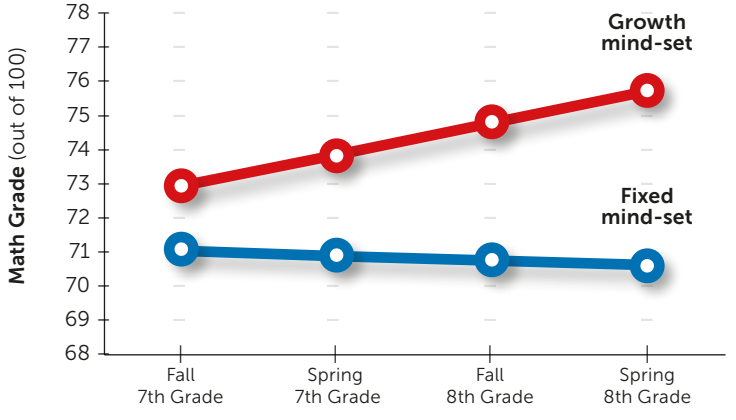
Young people who believe that their intelligence alone will enable them to succeed in school are often discouraged when the going gets tough.

PRECEDING PAGES: JIM CUMMINS *Getty Images*; THIS PAGE: F1 (*student*): SOURCE: "IMPLICIT THEORIES OF INTELLIGENCE PREDICT ACHIEVEMENT ACROSS AN ADOLESCENT TRANSITION: A LONGITUDINAL STUDY AND AN INTERVENTION," BY L. S. BLACKWELL, K. H. TRZESNIEWSKI AND C. S. DWECK, IN *CHILD DEVELOPMENT*, VOL. 78, NO. 1; JANUARY/FEBRUARY 2007 (*graph*)

Others, meanwhile, focused on fixing errors and honing their skills. One advised himself: "I should slow down and try to figure this out." Two schoolchildren were particularly inspiring. One, in the wake of difficulty, pulled up his chair, rubbed his hands together, smacked his lips and said, "I love a challenge!" The other, also confronting the hard problems, looked up at the experimenter and approvingly declared, "I was *hoping* this would be informative!" Predictably, the students with this attitude outperformed their cohorts in these studies.

Mind-set and Math Grades

Students who believed that intelligence is malleable (*growth mind-set line*) earned higher math grades in seventh and eighth grade than those who believed in static intelligence (*fixed mind-set line*), even though the two groups had equivalent math scores in the sixth grade. The grades of the growth mind-set group then improved over the two years, whereas the grades of the fixed mind-set students declined.



TWO VIEWS OF INTELLIGENCE

Several years later I developed a broader theory of what separates the two general classes of learners—helpless versus mastery-oriented. I realized that these different types of students not only explain their failures differently, but they also hold different "theories" of intelligence. The helpless ones believe that intelligence is a fixed trait: you have only a certain amount, and that's that. I call this a "fixed mind-set." Mistakes crack their self-confidence because they attribute errors to a lack of ability, which they feel powerless to change. They avoid challenges because challenges make mistakes more likely and looking smart less so. Like Jonathan, such children shun effort in the belief that having to work hard means they are dumb.

The mastery-oriented children, on the other hand, think intelligence is malleable and can be developed through education, hard work, good strategies and help from others. They want to learn above all else. After all, if you believe that you can expand your intellectual skills,

you want to do just that. Because slipups stem from a lack of effort or acquirable skills, not fixed ability, they can be remedied. Challenges are energizing rather than intimidating; they offer opportunities to learn. Students with such a growth mind-set, we predicted, were destined for greater academic success and were quite likely to outperform their counterparts.

We validated these expectations in a study published in early 2007. Psychologists Lisa Blackwell, then at Columbia University, and Kali H. Trzesniewski, then at Stanford University, and I monitored 373 students for two years during the transition to junior high school, when the work gets more difficult and the grading more stringent, to determine how their mind-sets might affect their math grades. At the beginning of seventh grade, we assessed the students' mind-sets by asking them to agree or disagree with statements such as "Your intelligence is something very basic about you that you can't really change." We then assessed their beliefs about other aspects of learning and looked to see what happened to their grades.

As we had predicted, the students with a growth mind-set felt that learning was a more important goal in school than getting good grades. In addition, they held hard work in high regard, believing that the more you labored at something, the better you would become at it. They understood that even geniuses have to work hard for their great accomplishments. Confronted by a setback such as a disappointing test grade, students with a growth mind-set said they would study harder or try a different strategy for mastering the material.

The students who held a fixed mind-set, however, were concerned about looking smart with less regard for learning. They had negative views of effort, believing that having to work hard at something was a sign of low ability. They thought that a person with talent or intelligence did not need to work hard to do well. Attributing a bad grade to their own lack of ability, those with a fixed mind-set said that they would study *less* in the future, try never to take that subject again

A for Effort

According to a survey we conducted in the mid-1990s, 85 percent of parents believed that praising children's ability or intelligence when they perform well is important for making them feel smart. But our work shows that praising a child's intelligence makes a child fragile and defensive. So, too, does generic praise that suggests a stable trait, such as "You are a good artist." Praise can be very valuable, however, if it is carefully worded. Praise for the specific process a child used to accomplish something fosters motivation and confidence by focusing children on the actions that lead to success. Such process praise may involve commending effort, strategies, focus, persistence in the face of difficulty, and willingness to take on challenges. The following are examples of such communications:

You did a good job drawing. I like the detail you added to the people's faces.

You really studied for your social studies test. You read the material over several times, outlined it and tested yourself on it. It really worked!

I like that you took on that challenging project for your science class. It will take a lot of work—doing the research, designing the apparatus, making the parts and building it. You are going to learn a lot of great things.

I like the way you tried a lot of different strategies on that math problem until you finally got it.

That was a hard English assignment, but you stuck with it until you got it done. You stayed at your desk and kept your concentration. That's great!

Parents and teachers can also teach children to enjoy the process of learning by expressing positive views of challenges, effort and mistakes. Here are some examples:

AGE FOTOSTOCK

Boy, this is hard—this is fun.

Oh, sorry, that was too easy—no fun. Let's do something more challenging that you can learn from.

Let's all talk about what we struggled with today and learned from. I'll go first.

Mistakes are so interesting. Here's a wonderful mistake. Let's see what we can learn from it. —C.S.D.

and consider cheating on future tests.

Such divergent outlooks had a dramatic impact on performance. At the start of junior high, the math achievement test scores of the students with a growth mind-set were comparable to those of students who displayed a fixed mind-set. But as the work became more difficult, the students with a growth mind-set showed greater persistence. As a result, their math grades surpassed those of the other students by the end of the first semester—and the gap between the two groups continued to widen during the two years we followed them [*see box on page 13*].

Along with psychologist Heidi Grant Halvorson, now at Columbia University, I found a similar relation between mind-set and achievement in a 2003 study of 128 Columbia freshman premed students who were enrolled in a challenging general chemistry course. Although all the students cared about grades, the ones who earned the best grades were those who placed a high premium on learning rather than on showing that they were smart in chemistry. The focus on learning strategies, effort and persistence paid off for these students.

In tutorials that advance a growth mind-set, students discover that learning promotes the formation of stronger connections among neurons in the brain.

CONFRONTING DEFICIENCIES

A belief in fixed intelligence also makes people less willing to admit to errors or to confront and remedy their deficiencies in school, at work and in their social relationships. In a study published in 1999 of 168 freshmen entering the University of Hong Kong, where all instruction and coursework are in English, three Hong Kong colleagues and I found that students with a growth mind-set who scored poorly on their English proficiency exam were far more inclined to take a remedial English course than were low-scoring students with a fixed mind-set. The students with a stagnant view of intelligence were presumably unwilling to admit to their deficit and thus passed up the opportunity to correct it.

A fixed mind-set can similarly hamper communication and progress in the workplace by leading managers and employees to discourage or ignore constructive criticism and advice. Research by psychologists Peter Heslin, now at the University of New South Wales in Australia, Don Vandewalle of Southern Methodist University and Gary Latham of the University of Toronto shows that managers who have a fixed mind-set are less likely to seek or welcome feedback from their employees than are managers with a growth mind-set. Presumably, managers with a growth mind-set see themselves as works-in-progress and understand that they need feedback to improve, whereas bosses with a fixed mind-set are more likely to see criticism as reflecting their underlying level of competence. Assuming that other people are not capable of changing either, executives with a fixed mind-set are also less likely to mentor their underlings. But after Heslin, Vandewalle and Latham gave managers a tutorial on the value and principles of the growth mind-set, supervisors became more willing to coach their employees and gave more useful advice.

Mind-set can affect the quality and longevity of personal relationships as well, through people's willingness—or unwillingness—to deal with difficulties. Those with a fixed mind-set are less likely than those with a growth mind-set to broach problems in their relationships and to try to solve them, according to a 2006 study I conducted with psychologist Lara Kammrath, now at Wake Forest University. After all, if you think that human personality traits are more or less fixed, relationship repair seems largely futile. Individuals who believe people can change and grow, however, are more confident that confronting concerns in their relationships will lead to resolutions.

PROPER PRAISE

How do we transmit a growth mind-set to our children? One way is by telling stories about achievements that result from hard work, good strategies, and help or input from others. For instance,

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MEHAU KULYK *Science Source*

talking about mathematical geniuses who were more or less born that way puts students in a fixed mind-set, but descriptions of great mathematicians who fell in love with math and developed amazing skills engenders a growth mind-set, our studies have shown. People also communicate mind-sets through praise [*see box on page 14*]. Although many, if not most, parents believe that they should build up children by telling them how brilliant and talented they are, our research suggests that this is misguided.

In studies involving several hundred fifth graders published in 1998, for example, psychologist Claudia M. Mueller, now at Stanford, and I gave children questions from a nonverbal IQ test. After the first 10 problems, on which most of the students did fairly well, we praised them. We praised some of them for their intelligence: "Wow … that's a really good score. You must be smart at this." We commended others for their process: "Wow … that's a really good score. You must have worked really hard."

We found that praising students' intelligence encouraged a fixed mind-set more often than did praising their learning process. Those congratulated for their intelligence, for example, shied away from a challenging assignment—they wanted an easy one instead—far more often than the kids applauded for their process. (Most of those lauded for their hard work wanted the difficult problem set from which they would learn.) When we gave everyone hard problems anyway, those praised for being smart became discouraged, doubting their ability. And their scores, even on an easier problem set we gave them afterward, declined as compared with their previous results on equivalent problems. In contrast, students praised for their hard work did not lose confidence when faced with the harder questions, and their performance improved markedly on the easier problems that followed [*see box on opposite page*].

The most persistent students do not ruminate about their own failure but think of mistakes as problems to be solved.

MAKING UP YOUR MIND-SET

In addition to encouraging a growth mind-set through praise for effort and strategies, parents and teachers can help children by providing explicit instruction regarding the mind as a learning machine. Blackwell, Trzesniewski and I designed an eight-session workshop for 91 students whose math grades were, on average, declining in their first year of junior high. Forty-eight of the students received instruction in study skills only, whereas the others attended a combination of study skills sessions and classes in which they learned about the growth mind-set and how to apply it to schoolwork.

In the growth mind-set classes, students read and discussed an article entitled "You Can Grow Your Brain." They

Chemist Marie Curie (*left*) and inventor Thomas A. Edison (*right*) developed their genius through passion and tremendous effort.

BETTMANN/CORBIS

were taught that the brain is like a muscle that gets stronger with use and that learning prompts neurons in the brain to grow new or stronger connections. From such instruction, many students began to see themselves as agents of their own brain development. Students who had been disruptive or bored sat still and took note. One particularly unruly boy looked up during the discussion and said, "You mean I don't have to be dumb?"

As the semester progressed, the math grades of the kids who learned only study skills continued to decline, whereas those of the students given the growth mind-set training stopped falling and began to bounce back to their former levels. Despite being unaware that there were two types of instruction, teachers reported noticing significant motivational changes in 27 percent of the children in the growth mind-set workshop as compared with only 9 percent of students in the control group. One teacher wrote: "Your workshop has already had an effect. L [our unruly male student], who never puts in any extra effort and often doesn't turn in homework on time, actually stayed up late to finish an assignment early so I could review it and give him a chance to revise it. He earned a B+. (He had been getting Cs and lower.)"

Other researchers have obtained similar results. Psychologists Catherine Good, now at Baruch College, Joshua Aronson of New York University and Michael Inzlicht, now at the University of Toronto, reported in 2003 that a growth mind-set workshop raised the math and English achievement test scores of seventh graders. In a 2002 study Aronson, Good (then a graduate student at the University of Texas at Austin) and their colleagues found that college students began to enjoy their schoolwork more, value it more and get better grades as a result of training that fostered a growth mind-set.

We have now encapsulated such instruction in an interactive computer program called Brainology. Its five modules teach students about the brain—what it does and how to make it work better. In a virtual brain lab, users can click on brain regions to determine their functions or on nerve endings to see how connections form or strengthen when people learn. Users can also advise virtual students with problems as a way of practicing how to handle schoolwork difficulties; additionally, users keep an online journal of their study practices.

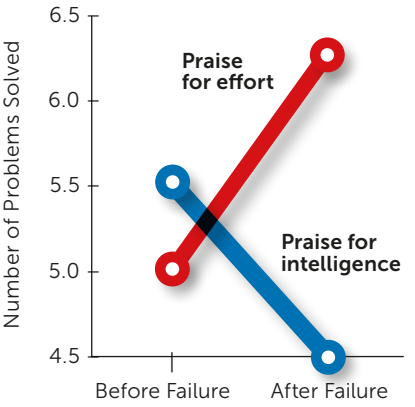
New York City seventh graders who tested Brainology reported that the program had changed their view of learning and how to promote it. One wrote: "My favorite thing from Brainology is the neurons part where when u [sic] learn something there are connections and they keep growing. I always picture them when I'm in school." A teacher said of the students who used the program: "They offer to practice, study, take notes, or pay attention to ensure that connections will be made."

Teaching children such information is not just a ploy to get them to study. People may well differ in the level of their talents and abilities. And yet research is converging on the conclusion that great accomplishment, and even what we call genius, is typically the result of years of passion and dedication and not something that flows naturally from a gift. Mozart, Edison, Curie, Darwin and Cézanne were not simply born with talent; they cultivated it through tremendous and sustained effort, good strategies and input from others. Similarly, hard work and discipline contribute more to school achievement than IQ does.

Such lessons apply to almost every human endeavor. For instance, many young athletes value talent more than hard work and have consequently become unteachable. Similarly, many people accomplish little in their jobs without constant praise and encouragement to maintain their motivation. If we foster a growth mind-set in our homes and schools, however, we will give our children the tools to succeed in their pursuits and to become productive workers and citizens. **M**

The Effects of Praise

Children praised for their intelligence solved significantly fewer problems after a failure than they had before encountering difficulty. In contrast, children praised for their effort solved *more* problems after their brush with adversity than they had before it.



SOURCE: "PRAISE FOR INTELLIGENCE CAN UNDERMINE CHILDREN'S MOTIVATION AND PERFORMANCE," BY C. M. MUELLER AND C. S. DWECK, IN *JOURNAL OF PERSONALITY AND SOCIAL PSYCHOLOGY*, VOL. 75, NO. 1; JULY 1998

MORE TO EXPLORE

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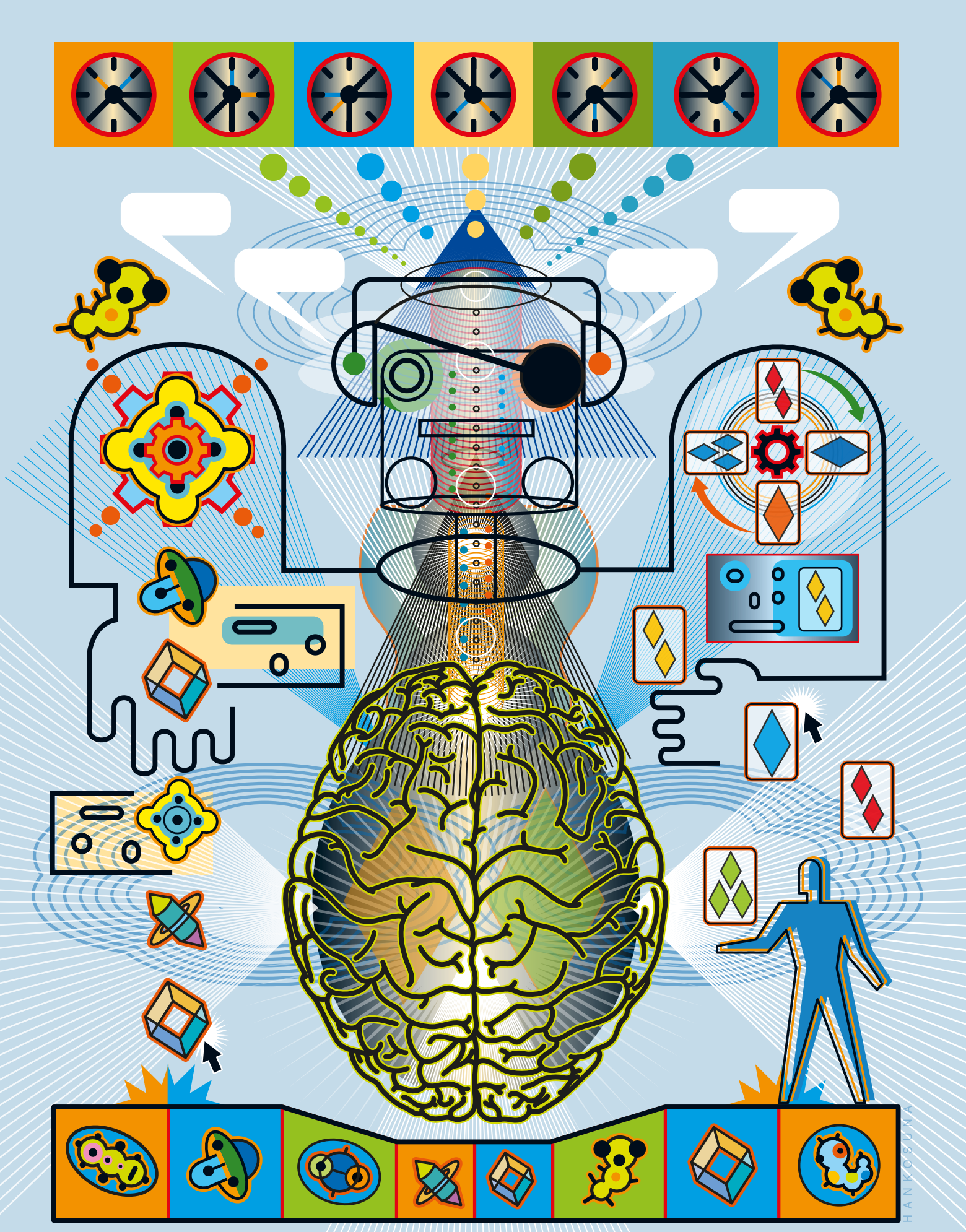


CALISTHENICS FOR A CHILD'S MIND

Scientists have concocted mental fitness regimens to strengthen weak thinking skills in students—in effect, making kids smarter

RAISE GREAT KIDS

By
Ingrid Wickelgren

Illustration by
Hank Osuna

In a classroom at Eaton Arrowsmith School in Vancouver, B.C., students work independently on computerized and paper-based exercises designed to bolster basic mental processes such as memory and reasoning.

COURTESY OF SANDRA HEUSEL *Eaton Educational Group*

A mop of light brown hair shakes as a slender nine-year-old boy named Jack bangs furiously at his keyboard. Jack's eyes are fixed on a clock with six hands, which denote the month, day, hour, minute, second and 60th of a second. As soon as he types 10:28:2:14:56:32, a new clock appears, and he hammers out another set of numbers. An affable 14-year-old student named Marti had just taught me the exercise, and I guessed I could have solved one of these clocks in a few minutes. Jack was finishing one every seven seconds.

Jack's incessant clacking is virtually the only sound in this small classroom of eight- and nine-year-olds. The others work silently. One or two wear an eye patch, copying symbols onto grids. A dark-haired girl listens through headphones to a list of words she must memorize and repeat to a teacher. One boy stares at a Norman Rockwell painting; his job is to extract its main idea and write it down.

Jack, his long red sleeves poking out from under a blue school T-shirt with the initials "EAS," cracks clock codes for 35 minutes almost nonstop. As with others at Eaton Arrowsmith School, a private facility for the learning disabled on the second floor of a building on the campus of the University of British Columbia in Vancouver, Jack attends six periods of brain exercises, among them reading clocks, copying symbols, tracing complex designs, memorizing patterns and performing mental arithmetic. Jack has one period of English and one period of mathematics, but none of his other classes resemble those in an ordinary school.

Arrowsmith students do not learn about the branches of government or genres of literature. Their time is devoted instead to fortifying mental processes such as attention, memory and reasoning. For decades, psychologists have thought that such fundamental thinking capacities were fixed. In research circles, evidence is mounting that they may not be.

The Arrowsmith program is intensive, requiring students to dedicate 80 percent of their day for three to four years to brain remediation before returning to regular school. Although the school boasts a number of success stories, support for its regimen's effectiveness is mainly anecdotal. Nevertheless, a commitment to its style of brain fitness for children is gathering steam in the scientific, clinical and even mainstream educational communities.

A small collection of brain-training workouts has emerged from neuroscience and psychology laboratories in recent years, and several are now being marketed and sold. Some build working (short-term) memory, a kind of mental whiteboard that is linked to intelligence. Others target basic number sense, for math, or sound perception, for reading. Another trains reasoning.

In many cases, the tools are aimed at learning problems such as dyslexia, dyscalculia or attention-deficit/hyperactivity disorder (ADHD). But some educators are starting to offer brain training

FAST FACTS

BEEFING UP YOUNG BRAINS

1. Psychologists long believed that thinking capacities such as attention, memory and reasoning are fixed, but evidence is mounting that they are not.
2. A smattering of brain-training workouts has emerged from neuroscience and psychology laboratories, and several of the programs are now being marketed and sold.
3. In many cases, the brain workouts are aimed at kids with learning problems, but some educators are offering them to all children as part of regular instruction.

to the general school population. "I see the technology as making it possible to individualize training and learning for everybody," says psychologist Allyson P. Mackey of the Massachusetts Institute of Technology. "Even kids performing fairly well might have a weakness, and if you patch that up, they would perform much better."

The extent to which children can overcome intellectual deficits or raise their IQ through mental calisthenics is largely unknown. Although data suggest that the training can be useful, it does not always work. In addition, researchers are only now beginning to explore whether the measured gains in children's thinking skills translate into academic achievement.

Still, many scientists and educators believe that with the proper tools, students can increase their intellectual capacity—an idea that could transform lives. "The question is: What are we capable of as human beings?" asks Howard Eaton, a learning disabilities specialist who founded Eaton Arrowsmith. The notion that people can fundamentally alter their brain, he says, "changes your whole perspective on human possibility."

"I see the technology as making it possible to individualize training and learning for everybody," says one psychologist.

LEVERS FOR LEARNING

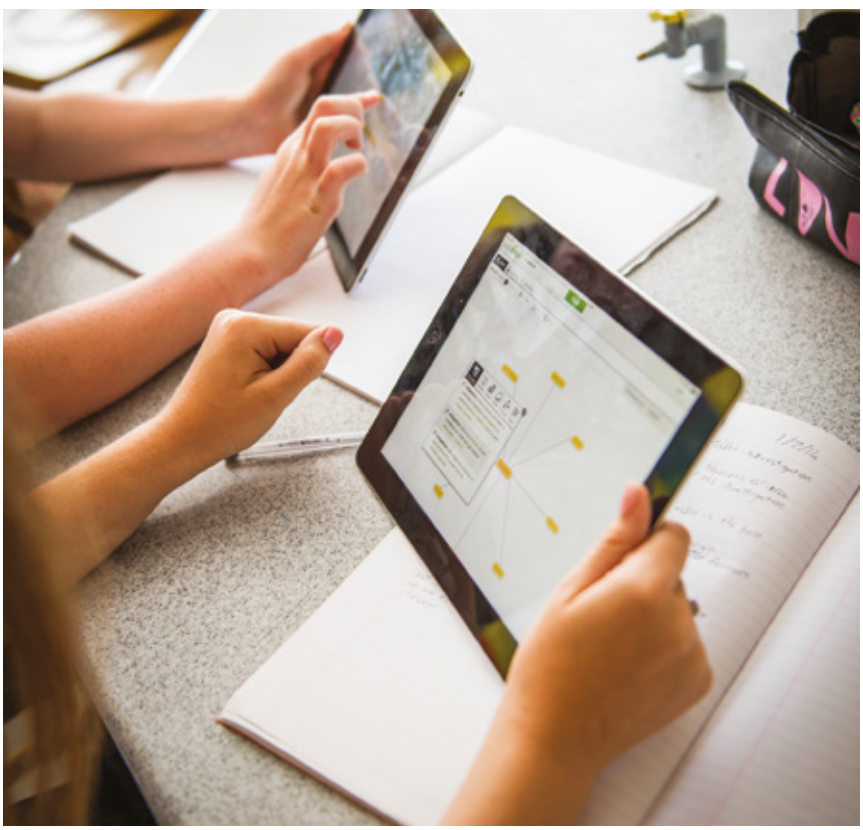
Of course, school has long been based on the premise that the brain is flexible: learning new information and skills involves changes at the neural level. Yet people have assumed that a person's *capacity* to learn is fairly stable. Part of this capacity lies in executive functions, a set of faculties governed by a structure called the prefrontal cortex that sits just behind the forehead. These faculties are working memory, cognitive flexibility—the ability to find alternative solutions to problems and shift from one idea or action to another—and self-regulation, the ability to inhibit competing or inappropriate actions.

School is not traditionally designed to alter executive function, nor is it typically structured to tweak basic math ability or facility for listening to language. It does not do these things, in part because people assumed those basics of the brain were immovable.

But it is no secret that environment can have a powerful effect on intellectual capacity. Stressful circumstances such as those that accompany poverty, for example, can virtually shut down executive functions. A child's socioeconomic class can also strongly influence language skills that are fundamental to reading. "For a four- or five-year-old, the difference in language exposure between a child from a low socioeconomic class and one from a high socioeconomic class can be as much as 30 million words," says neuroscientist William M. Jenkins, chief scientific officer at Scientific Learning in Oakland, Calif.

In that light, the notion that tailored coaching could *boost* a child's potential to learn is less difficult to fathom. In recent years researchers have designed

Researchers are now beginning to explore whether brain-training workouts enhance thinking skills in kids and whether those gains translate into better academic achievement.



GETTY IMAGES

curricula to promote self-regulation, a skill essential to both academic success and social and emotional maturity. Meanwhile other scientists have set out to design interventions aimed more squarely at an individual child's intellectual capacity.

One critical lever on intellect is working memory. Various cognitive skills depend on this mental scratch pad. Attention, in particular, entails mentally taking note of important information. "If you can't hold a plan in mind, you'll get distracted," says cognitive neuroscientist Torkel Klingberg of the Karolinska Institute in Sweden.

In 1997 Klingberg was studying the neural basis of working memory when he came across a paper showing that kids with ADHD very often had limited working memory capacity. Although working memory was widely believed to be a static trait, Klingberg was radically optimistic about its pliability. "I thought of it as a muscle that could be trained," he recalls.

With attention deficits in mind, Klingberg and his colleagues created workouts for recalling locations—such as directions to a shopping mall—as well as verbal information. In some exercises, users try to reproduce the order in which an array of red bulbs or asteroids light up. As with all good training programs, these adapt to the child: as his or her performance improves, the game gets harder. At higher levels, the asteroids move, or the grid of lights rotates before the player has to recall the order. A verbal task requires remembering a series of digits and repeating it in reverse.

In a study published in 2005 by Klingberg's team, 22 kids aged seven to 12 who had severe attention problems played these games for 35 to 40 minutes a day for 25 days. The children improved significantly more on a standard assessment of working memory than did 22 kids with ADHD who used much easier versions of the same games. In addition, parents of the trained youths said their children became more attentive. Based on such results, Klingberg founded a company called Cogmed, now owned by Pearson, the education firm, to market the software. (Klingberg is no longer associated with Cogmed.)

Playing games such as Rush Hour (*above*) that require reasoning upped the IQ scores of kids from a low-income community.

Scientists have since garnered additional support for these games as remedies for ADHD. In 2010 psychologist William B. Benninger of Ohio State University and his colleagues found that children and adolescents with ADHD who did the drills at home became more attentive and better organized and had fewer symptoms, according to their parents, than those who did not exercise their recall. In 2012 psychologist Julie B. Schweitzer of the University of California, Davis, School of Medicine and her associates reported that the training significantly reduced "off-task" behavior in 12 children with ADHD while doing schoolwork—that is, looking away from a work sheet, a more real-world measure of focus.

Working memory can have a profound effect on learning in general. Among children who score in the lowest 10 percent of the population on working-memory tests, more than four fifths have considerable problems in reading or math, or both. From a test of 345 children between the ages of eight and 11, psychologist Darren L. Dunning, now at the University of East Anglia in England, and his colleagues identified 42 children who fell in the lowest 15 percent in working-memory ability. They assigned 22 of them to intensive, in-school Cogmed training for five to seven weeks; the others received a less taxing version of the program. By the end of the instruction, the children who did the more intensive exercises showed a big boost in all aspects of working memory, whereas the other kids reaped only minimal gains. Moreover, six months later the kids who got the real training scored significantly higher on a standardized test of mathematical reasoning than they had at the beginning of the trial, indicating that they used their trained brains to learn more math.

Among kids who score in the lowest 10 percent on working memory tests, more than four fifths have academic troubles.

GETTING OUT OF A JAM

Another critical component of academic success is reasoning, the capacity to

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THE AUTHOR

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think logically, connect ideas and solve problems in novel situations. Reasoning is a higher-level skill that depends on executive functions such as working memory and attention. The clock puzzles Jack solves so expertly are supposed to train reasoning by building a child's understanding of relations such as those between the different hands on a clock.

Several years ago M.I.T.'s Mackey, then a psychology graduate student at the University of California, Berkeley, wanted to see if she could sharpen reasoning in disadvantaged children. Collaborating with her colleague, psychologist Silvia A. Bunge, Mackey selected computer and commercial board games that rely heavily on reasoning. In one board game, called Rush Hour, players need to figure out how to get a car to escape a traffic jam while still obeying the laws of the road. Other games depended on logic or on integrating different pieces of information.

They asked 17 students, aged seven to 10, from an elementary school in a high-poverty neighborhood in Oakland, Calif., to play the games for an hour a day, two days a week, for eight weeks. Another 11 students played games that taxed processing speed—how quickly they could make sense of information—instead. The kids who played the reasoning games saw their scores jump by more than 30 percent on a standard test of that skill—and their IQ scores rose 10 points on average. The students who played games that exercised processing speed upped their ranking on a test of that ability by 30 percent. "We were really surprised at how big the gains were," Mackey says.

She is now trying to reproduce her results in a larger sample of kids at risk for school failure and determine whether the training translates into gains in academic achievement. "If we can show these kinds of games lead to better test scores, we've taken a huge step forward," Mackey notes.

In a 2014 study, Andrea Paula Goldin of the University of Buenos Aires and her colleagues took that step with computer training. They asked half of more than 100 six-year-olds from disadvantaged backgrounds to play three challenging computer games designed to train working memory, planning and inhibitory control. They found that the 10-week intervention improved grades in math and language arts among those who received the cognitive training and whose grades were low at the start of the study.

KLAUS VEDFELT *Getty Images*

Exercises that require students to hold information in their mind, such as directions to a shopping mall, can improve children's working memory. This also helps to enhance attention and general learning.

FIVE DOTS OR SIX?

Computerized training programs can bolster basic math ability, too. Doing mental math depends heavily on working memory, which we use to hold and manipulate numbers. One Arrowsmith exercise involves adding one small number to the next as the digits appear sequentially, keeping a running total, and reporting the sum at the end.

Other programs train number sense, a basic sense of quantity that enables us to immediately compare, say, the number of dots in two different arrays or subtract or add dots. Scientists have tied this sense to a location in the brain: a narrow indentation on its surface called the intraparietal sulcus. Without a well-developed sense of number, children will have trouble with math and may develop dyscalculia, a mathematical learning disability that afflicts up to 7 percent of the school-aged population. A nine-year-old with dyscalculia might, for example, confuse five dots with six or be unable to say whether 50 is greater or less than 100.

About 10 years ago neuroscientist Stanislas Dehaene of the French National Institute of Health and Medical Research and his colleagues created a Web-based game called Number Race, in which players compare quantities of dots and associate them with number symbols and learn some basic addition and subtraction facts. In 2006 the researchers reported that 15 seven- to nine-year-olds with dyscalculia who played Number Race got somewhat better at comparing numbers, making quick visual assessments of quantity and subtracting one-digit numbers [see "How to Build a Better Learner," by Gary Stix, on page 26].

Three years later the researchers tested the software on younger children at risk for math difficulties: 53 French kindergartners from low socioeconomic backgrounds. Some of the children played Number Race for six 20-minute sessions, and others used a commercially available reading program, after which the kids switched tasks. Number Race, but not the reading software, improved the kids' ability to compare num-

bers represented as symbols, suggesting that the program honed the ability to connect number symbols to quantity. The team has since developed a more advanced game, called Number Catcher, that exercises basic calculation skills and represents numbers in different ways.

Lumosity, a company based in San Francisco, offers a suite of brain-training games aimed at various capacities, including several related to math. One involves arithmetic problems that appear in falling raindrops that must be solved before the drops splash into water at the bottom of the screen. In another, users compare the value of mathematical expressions presented in pairs.

Such drills have shown promise in boosting math proficiency in children with inborn impediments to learning the subject. In a 2011 pilot study, psychiatrist Shelli R. Kesler of Stanford University and her colleagues found that playing these games 20 minutes a day for six weeks ameliorated characteristic math-related deficiencies in 16 girls who had a genetic condition called Turner syndrome. After the training, the girls scored significantly higher on tests of number sense, processing speed and cognitive flexibility.

SOUNDING IT OUT

As with math, reading involves a complex set of intellectual capacities, including reasoning and executive skills. Dyslexia, a reading disability in which the brain has trouble recognizing and processing words, afflicts 5 to 17 percent of children. In the early 1990s neuroscientist Paula Tallal of Rutgers University hypothesized that a root cause in many cases was auditory, specifically a deficit in detecting rapid changes in similar sounds, such as "da" and "ba." Such difficulties, she argued, prevented children from acquiring good language skills, leading to dyslexia.

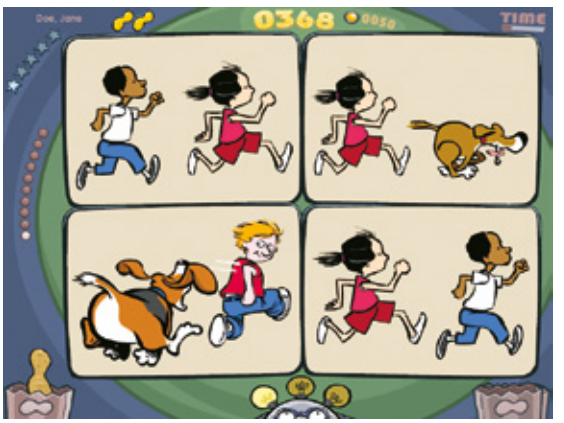
In 1996 Tallal and neuroscientist Michael Merzenich, now an emeritus professor at the University of California, San Francisco, founded Scientific Learning to develop computer software to correct auditory-processing problems in children with reading difficulties. The program, called Fast ForWord Language, helps children hear and discriminate phonemes by first slowing them down and emphasizing certain rapidly changing parts of speech, Jenkins says. Then it gradually speeds up and softens the emphasis. The software also morphs the sounds, making them more or less similar, depending on a child's proficiency.

Several small studies indicate that the program is helpful. In 2007 neuroscientist Nadine Gaab of Harvard Medical School, along with Tallal, among other colleagues, reported significant improvement in language and reading skills in 22 children with dyslexia who used the program 20 minutes a day five days a week for eight weeks. They also saw in these youngsters increased activation in brain circuitry responsible for processing rapidly changing sounds. In a 2015 study, a team led by neuroscientist Sabine Heim, also at Rutgers, revealed small changes in brain activity in 21 school-aged children with language impairments after a month of intensive training using Fast ForWord. The changes hinted at improvements in sound, language and cognitive processing in these children.

Not all studies back up Fast ForWord's efficacy, however. In a 2011 meta-analysis (quantitative review) of six large studies, psychologist Charles Hulme of the University of York in England, and his colleagues, concluded that the program had little effect on children's language or reading difficulties. The mixed results may reflect differences in how the software was tested, including the degree to which adults monitored its use and motivated children to engage with it. After all, kids who quit using the program out of frustration or boredom are unlikely to benefit. In addition, not all children with dyslexia suffer from auditory problems. Indeed, the latest versions of Fast ForWord are designed to serve a wider swath of the student population by drilling reading skills, from phonological awareness to comprehension strategies, along with executive functions.

GAMES IN THE MAINSTREAM

Most of the current student brain-training programs are aimed primarily at



A program called Fast ForWord Language asks users to distinguish sounds such as "ada" and "aba" by choosing the acorn that uttered the target phoneme (*left*) and to parse sentences such as "The girl is chasing the dog" by clicking on the picture the sentence describes (*right*).

COURTESY OF SCIENTIFIC LEARNING CORPORATION

RAISE GREAT KIDS

those with diagnosable deficits. The many U.S. schools that have adopted the Cogmed software, for example, typically offer it to students with attention deficits and other learning disabilities. More than 500 clinics in the U.S. and Canada also use Cogmed, primarily with clients who have ADHD.

Yet the programs are also trickling into the educational mainstream. Although Fast ForWord is geared toward kids with reading problems, many of the more than 4,000 schools that have the software include it as part of regular instruction. So far 14,000 students in more than 500 classrooms worldwide have played a suite of brain games offered through the Lumosity Education Access Program (LEAP), and more than a quarter of Lumosity.com online users are younger than 21. At least one private parochial school in New York City has made Cogmed software available to the kids in its fifth and sixth grades. "This isn't limited to students with learning difficulties," says Nicole F. Ng, a former teacher who now manages LEAP. "It applies to a healthy student who wants to improve cognitive capabilities."

Some data hint that brain training could benefit the typical learner. In an unpublished study that was conducted by Ng and her colleagues, 949 students aged six to 18 years in 43 schools played 28 Lumosity games for an average of six hours total during a semester. These youths raised their scores on a battery of neuropsychological tests significantly more than did 443 students who did not perform the exercises. The more hours a student trained, the more he or she improved on skills such as memory, processing speed and reasoning. Students who spent at least 10 hours of training saw measurable benefits, Ng says.

Yet doubts have emerged about the significance of those benefits. In October 2014 more than 70 psychologists and neuroscientists signed a statement released by the Stanford University Center on Longevity and the Max Planck Institute for Human Development in Berlin stating that there is scant scientific backing for claims that "brain games" can sharpen everyday mental functioning. And in January 2016 the Federal Trade Commission charged that Lumosity's ads were misleading in claiming that playing their games three to four times a week could boost performance at work or in school. Lumos Labs, the developer of the Lumosity games, paid $2 million to settle the charges.

Eventually the educational community may support adding at least a dollop of brain fitness to children's usual scholastic fare.

Before arriving at Eaton Arrowsmith, Marti had struggled in regular school. "I'd be staying up so late trying to reread and understand," she told me in 2012. "I ended up crying because I was overwhelmed with homework." Marti has since graduated from the program, and her ninth grade report card in December 2012 displayed straight As. School officials have data on numerous children who, like Marti, have been helped by the curriculum.

Outside scientists often find the Arrowsmith approach intriguing but say it lacks rigorous scientific support. "I saw one kid doing math on a computer faster than I could do it," says Adele Diamond, a developmental cognitive neuroscientist at the University of British Columbia. But, she warns, "I'd like to see data that it helps." Indeed, one small, eight-month investigation of the school's curriculum led by educational psychologist Linda Siegel, also at the University of British Columbia, failed to show that it significantly improved students' scores on a battery of cognitive and achievement tests. New data are likely forthcoming, however. Microsoft CEO Satya Nadella and his wife, Anu, donated $100,000 for brain imaging and other research to evaluate the Arrowsmith program.

Science does increasingly suggest that the brain is far more supple than we once assumed. Eventually the educational community may decide that the data support adding at least a dollop of brain fitness to children's usual scholastic fare. Although no one knows exactly the form such training will take, putting children's mental muscles through the paces on a regular basis could lead to lasting benefits. "I envision improvement of cognitive skills as part of education much more than it is right now," Mackey says. M

MORE TO EXPLORE

- **Differential Effects of Reasoning and Speed Training in Children.** Allyson P. Mackey et al. in *Developmental Science,* Vol. 14, No. 3, pages 583–590; May 2011.
- **Training the Brain: Practical Applications of Neural Plasticity from the Intersection of Cognitive Neuroscience, Developmental Psychology, and Prevention Science.** Richard L. Bryck and Philip A. Fisher in *American Psychologist,* Vol. 67, No. 2, pages 87–100; February–March 2012.
- **Will Working Memory Training Generalize to Improve Off-Task Behavior in Children with Attention-Deficit/Hyperactivity Disorder?** Chloe T. Green et al. in *Neurotherapeutics,* Vol. 9, No. 3, pages 639–648; July 2012.
- **Far Transfer to Language and Math of a Short Software-Based Gaming Intervention.** A. P. Golden et al. in *Proceedings of the National Academy of Sciences USA,* Vol. 111, No. 17, pages 6443–6448; April 29, 2014.

RAISE GREAT KIDS

HOW TO BUILD A BETTER LEARNER

By
Gary Stix

Brain studies suggest new ways to improve reading, writing and arithmetic—and even social skills

Photograph by
Andrew Hetherington

Thinking cap recorded electrical signals from the brain of Elise Hardwick when she was one year old. Such work is helping to reveal how young children process sounds that form the building blocks of language.

Eight-month-old Lucas Kronmiller has just had the surface of his largely hairless head fitted with a cap of 128 electrodes. A research assistant in front of him is frantically blowing

bubbles to entertain him. But Lucas seems calm and content. He has, after all, come here, to the Infancy Studies Laboratory at Rutgers University, repeatedly since he was just four months old, so today is nothing unusual. He—like more than 1,000 other youngsters before him—is helping April A. Benasich and her colleagues to find out whether, even at the earliest age, it is possible to ascertain if a child will go on to experience difficulties in language that will prove a burdensome handicap when first entering elementary school.

Benasich is one of a cadre of researchers who have been employing brain-recording techniques to understand the essential processes that underlie learning. The new science of neuroeducation seeks the answers to questions that have always perplexed cognitive psychologists and pedagogues.

How, for instance, does a newborn's ability to process sounds and images relate to the child's capacity to learn letters and words a few years later? What does a youngster's ability for staying mentally focused in preschool mean for later academic success? What can educators do to foster children's social skills—also vital in the classroom? Such studies can complement the wealth of knowledge established by psychological and educational research programs.

They also promise to offer new ideas, grounded in brain science, for making better learners and for preparing babies and toddlers for reading, writing, arithmetic, and survival in the complex social network of nursery school and beyond. Much of this work focuses on the first years of life and the early grades of elementary school, because some studies show that the brain is most able to change at that time.

THE AHA! INSTANT

Benasich studies anomalies in the way the brains of the youngest children perceive sound, a cognitive process fundamental to language understanding, which, in turn, forms the basis for reading and writing skills. Benasich, a former nurse, who later earned two doctorates, focuses on what she calls the aha! instant—an abrupt transition in electrical activity in the brain that signals that something new has been recognized.

Researchers at Benasich's lab in Newark, N.J., expose infants to tones of a certain frequency and duration. They then record a change in the electrical signals generated in the brain when a different frequency is played. Typically the electroencephalogram (EEG) produces a strong oscillation in response to the change—indicating that the brain essentially says, "Yes, something has changed;" a delay in the response time to the different tones means that the brain has not detected the new sound quickly enough.

The research has found that this pattern of sluggish electrical activity at six months can predict language issues at three to five years of age. Differences in activity that persist during the toddler and preschool years can foretell problems in development of the brain circuitry that processes the rapid transitions occurring during perception of the basic units of speech. If children fail to hear or process components of speech—say, a "da" or a "pa"—quickly enough as toddlers, they may lag in "sounding out" written letters or syllables in their head, which could later impede fluency in reading. These findings offer more rigorous confirmation of other research by Benasich showing that children who encounter early problems in processing these sounds test poorly on psychological tests of language eight or nine years later.

If Benasich and others can diagnose future language problems in infants, they may be able to correct them by exploiting the inherent plasticity of the developing brain—its capacity to change in response to new experiences. They may even be able to improve basic functioning for an infant whose brain is developing normally. "The easiest time to make sure that the brain is getting set up in a way that's optimal for learning may be in the first part of the first year," she says.

Games, even in the crib, could be one answer. Benasich and her team have devised a game toy that trains a baby to react to a change in tone by turning the head or shifting the eyes (detected with a tracking sensor). When the movement occurs, a video snippet plays, a reward for good effort.

In a study reported in 2014 babies who went through this training detected tiny modulations within the sounds fast-

FAST FACTS

EARLY EXERCISES

1. The technology and research methods of the neuroscientist have started to reveal, at the most basic level, what happens in the brain when we learn something new.
2. As these studies mature, it may become possible for a preschooler or even an infant to engage in simple exercises to ensure that the child is cognitively equipped for school.
3. If successful, such interventions could potentially have a huge effect on educational practices by dramatically reducing the incidence of various learning disabilities. But scientists, educators and parents must beware overstated claims for brain-training methods that purport to help youngsters but have not been proved to work.

er and more accurately than did children who only listened passively or had no exposure to the sounds at all. Based on this research, Benasich believes that the game would assist infants impaired in processing these sounds to respond more quickly. She is now working on an interactive game that could train infants to perceive rapid sound sequences.

THE NUMBER SENSE

Flexing cognitive muscles early on may also help infants tune rudimentary math skills. Stanislas Dehaene, a neuroscientist at the French National Institute of Health and Medical Research, is a leader in the field of numerical cognition who has tried to develop ways to help children with early math difficulties. Babies have some capacity for recognizing numbers from birth. When the skill is not in place from the beginning, Dehaene says, a child may later have difficulty with arithmetic and higher math. Interventions that build this "number sense," as Dehaene calls it, may help the slow learner avoid years of difficulty in math class.

This line of research contradicts that of famed psychologist Jean Piaget, who contended that the brains of infants are blank slates, or tabula rasa, when it comes to making calculations in the crib. Children, in Piaget's view, have to develop a basic idea of what a number is from years of interacting with blocks, Cheerios or other objects. They eventually learn that when the little oat rings get pushed around a table, the location differs, but the number stays the same.

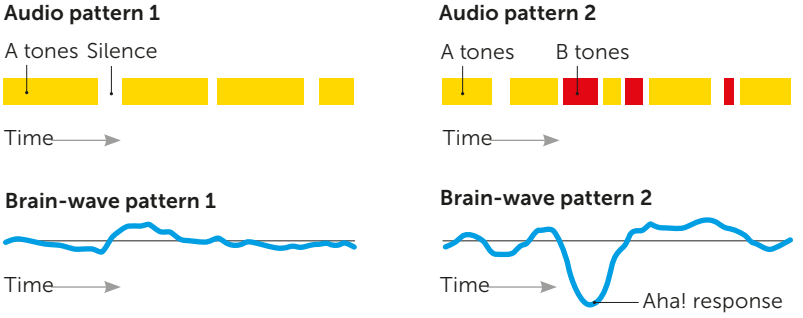
The neuroscience community has amassed a body of research showing that humans and other animals have a basic numerical sense. Babies, of course, do not spring from the womb performing differential equations in their head. But experiments have found that toddlers will routinely reach for the row of M&Ms that has the most candies. And other research has demonstrated that even infants only a few months old comprehend relative size. If they see five objects being hidden behind a screen and then another five added to the first set, they convey surprise if they see only five when the screen is removed.

Toning Up for Language: Early Education in the Crib

Scientists at Rutgers University have developed tests to determine whether babies with normal hearing process sound optimally deep within the brain (*top panel*). They are exploring whether a game they are devising (*bottom panel*) might ready the youngest children for speaking, listening, reading and writing.

Waiting for "Aha!"

The Infancy Studies Laboratory at Rutgers uses an electrode cap to record brain activity while babies listen to different sounds. First, they hear high-frequency tones (*labeled A*), which elicit a certain brain-wave pattern (*left*). Tones of different pitch (*labeled B*) intersperse with the initial tones and cause a temporary shift in the brain wave (the aha! response) as the brain detects the change (*right*). A slower or weaker response to this sudden change in pitch may predict language problems in later life.



A Game for Babies

Infants at Rutgers can learn to process sound more efficiently while also having fun. A child learns to turn the head in response to the B tones (*left*) but not to the A tones (*right*) and is rewarded with a snippet of a video for a correct response. The pace of tone sequences speeds up, and the child learns to respond more and more accurately to this fast tempo.

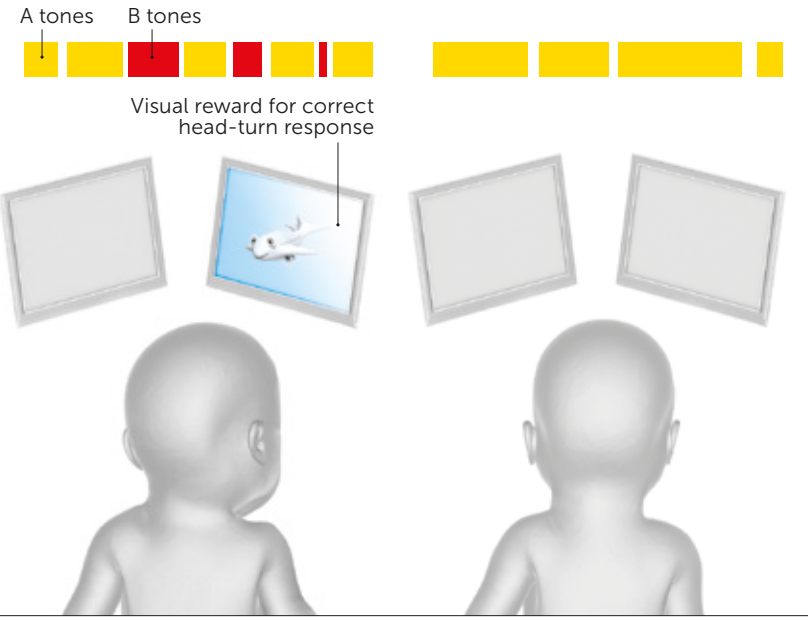


ILLUSTRATION BY BRYAN CHRISTIE, GRAPHICS BY JEN CHRISTIANSEN; SOURCES: CYNTHIA ROESLER, APRIL A. BENASICH, TERESA REALPE AND NASEEM CHOUDHURY *Rutgers University*

Babies also seem to be born with other innate mathematical abilities. Besides being champion estimators, they can also distinguish exact numbers—but only up to the number three or four. Dehaene was instrumental in pinpointing a brain region—a part of the parietal lobe (the intraparietal sulcus)—where numbers and approximate quantities are represented. (Put a hand on the rear portion of the top of your head to locate the parietal lobe.)

The ability to estimate group size, which also exists in dolphins, rats, pigeons, lions and monkeys, is probably an evolutionary hand-me-down that is required to gauge whether your clan should fight or flee in the face of an enemy and to ascertain which tree bears the most fruit for picking. Dehaene, along with linguist Pierre Pica of the National Center for Scientific Research in France and colleagues, discovered more evidence for this instinctive ability through work with the Mundurukú Indians in the Brazilian Amazon, a tribe that has only an elementary lexicon for numbers. Its adult members can tell whether one array of dots is bigger than another, performing the task almost as well as a French control group did, yet most are unable to answer how many objects remain when four objects are removed from a group of six.

This approximation system is a cornerstone on which more sophisticated mathematics is constructed. Any deficit in these innate capacities can spell trouble later. In the early 1990s Dehaene hypothesized that children build on their internal ballpark estimation system for more sophisticated computations as they get older. Indeed, in the years since then, a number of studies have found that impaired functioning of the primitive numerical estimation system in youngsters can predict that a child will perform poorly in arithmetic and standard math achievement tests from the elementary years onward. "We realize now that the learning of a domain such as arithmetic has to be founded on certain core knowledge that is available already in infancy," Dehaene says.

It turns out that dyscalculia (the computational equivalent of dyslexia), which is marked by a lag in computational skills, affects 3 to 7 percent of children. Dyscalculia has received much less attention from educators than dyslexia has for reading—yet it may be just as crippling. "They earn less, spend less, are more likely to be sick, are more likely to be in trouble with the law, and need more help in school," notes a review article that appeared in May 2011 in *Science*.

As with language, early intervention may help. Dehaene and his team devised a simple computer game they hope will enhance mathematical ability. Called the Number Race, it exercises these basic abilities in children aged four to eight. In one version, players must choose the larger of two quantities of gold pieces before a computer-controlled opponent steals the biggest pile. The game adapts automatically to the skill of the player, and at the higher levels the child must add or subtract gold before making a comparison to determine the biggest pile. If the child wins, he or she advances forward a number of steps equal to the gold just won. The first player to get to the last step on the virtual playing board wins.

The open-source software, which has been translated into eight languages, makes no hyperbolic claims about the benefits of brain training. Even so, more than 20,000 teachers have downloaded the software from a government-sup-

Count on It: Born to Estimate

From the time we are born, we have some concept of number. Children with deficits in this innate skill often end up struggling in later life. Stanislas Dehaene and his colleagues have created a game, the Number Race, intended to bolster our natural-born ability to estimate quantity. A preschooler judges which group of gold pieces is larger before the computer's animal avatar can steal the bigger pile (*top left*). A correct guess by the child advances his or her avatar a comparable number of spaces from its previous position; the loser moves ahead by a number equal to the smaller quantity of coins (*bottom right*). The winner is the one to reach the end of the number line first.

ILLUSTRATION BY QUICKHONEY; MODIFIED FROM "PRINCIPLES UNDERLYING THE DESIGN OF 'THE NUMBER RACE.' AN ADAPTIVE COMPUTER GAME FOR REMEDIATION OF DYSCALCULIA," BY ANNA J. WILSON, STANISLAS DEHAENE, PHILIPPE PINEL, SUSANNAH K. REVKIN, LAURENT COHEN AND DAVID COHEN, IN *BEHAVIORAL AND BRAIN FUNCTIONS*, VOL. 2: 2006

ported research institute in Finland. Dehaene is launching a randomized trial this fall involving 1,000 students, to test whether Number Race (and other brain games his group is developing) prevents dyscalculia and whether it helps healthy children bolster their basic number sense.

GET AHOLD OF YOURSELF

The cognitive foundations of good learning depend heavily on what psychologists call executive function, a term encompassing such cognitive attributes as the ability to be attentive, hold what you have just seen or heard in the mental scratch pad of working memory, and delay gratification. These capabilities may predict success in school and even in the working world. In 1972 a famous experiment at Stanford University—"Here's a marshmallow, and I'll give you another if you don't eat this one until I return"—showed the importance of executive function. Children who could wait, no matter how much they wanted the treat, did better in school and later in life.

In the 21st century experts have warmed to the idea of executive function as a teachable skill. An educational curriculum called Tools of the Mind has had success in some low-income school districts, where children typically do not fare as well academically compared with high-income districts. The program trains children to resist temptations and distractions and to practice tasks designed to enhance working memory and flexible thinking.

In one example of a self-regulation task, a child might tell himself or herself aloud what to do. These techniques are potentially so powerful that in centers of higher learning, economists now contemplate public policy measures to improve self-control as a way to "enhance the physical and financial health of the population and reduce the rate of crime," remark the authors of a study that appeared in 2011 in the *Proceedings of the National Academy of Sciences USA*.

Findings from neuroscience labs have bolstered that view and have revealed that the tedium of practice to resist metaphorical marshmallows may not be necessary.

5 Common Myths about the Brain

Some widely held ideas about the way children learn can lead educators and parents to adopt faulty teaching principles.

MYTH	FACT
Humans use only 10 percent of their brain	The 10 percent myth (sometimes elevated to 20) is mere urban legend, one perpetrated by the plot of the 2011 movie *Limitless,* which pivoted around a wonder drug that endowed the protagonist with prodigious memory and analytical powers. In the classroom, teachers may entreat students to try harder, but doing so will not light up "unused" neural circuits; academic achievement does not improve by simply turning up a neural volume switch.
"Left brain" and "right brain" people differ	The contention that we have a rational left brain and an intuitive, artistic right side is fable: humans use both hemispheres of the brain for all cognitive functions. The left brain/right brain notion originated from the realization that many (though not all) people process language more in the left hemisphere and spatial abilities and emotional expression more in the right. Psychologists have used the idea to explain distinctions between different personality types. In education, programs emerged that advocated less reliance on rational "left brain" activities. Brain-imaging studies show no evidence of the right hemisphere as a locus of creativity. And the brain recruits both left and right sides for both reading and math.
You must speak one language before learning another	Children who learn English at the same time as they learn French do not confuse one language with the other and so develop more slowly. This idea of interfering languages suggests that different areas of the brain compete for resources. In reality, young children who learn two languages, even at the same time, gain better generalized knowledge of language structure as a whole.
Brains of males and females differ in ways that dictate learning abilities	Differences do exist in the brains of males and females, and the distinctive physiology may result in differences in the way their brains function. No research, though, has demonstrated gender-specific differences in how networks of neurons become connected when we learn new skills. Even if some gender differences do eventually emerge, they will likely be small and based on averages—in other words, they will not necessarily be relevant to any given individual.
Each child has a particular learning style	The notion that a pupil tends to learn better by favoring a particular form of sensory input—a "visual learner" as opposed to one who listens better—has not received much validation in actual studies. For this and other myths, public perceptions appear to have outstripped the science. Uta Frith, a neuroscientist who chaired a British panel that looked at the promise of neuroeducation, urges parents and educators to tread cautiously: "There is huge demand by the general public to have information about neuroscience for education. As a consequence, there's an enormous supply of totally untested, untried and not very scientific methods."

SOURCES: *MIND, BRAIN, AND EDUCATION SCIENCE*, BY TRACEY TOKUHAMA-ESPINOSA. W. W. NORTON, 2010; *UNDERSTANDING THE BRAIN: THE BIRTH OF A LEARNING SCIENCE*. OECD, 2007; OECD EDUCATIONAL MINISTERIAL MEETING, NOVEMBER 4–5, 2010

Music training can work as well. Researchers are finding that assiduous practice of musical instruments may yield a payoff in the classroom—invoking shades of "tiger mom" author Amy Chua, who insisted that her daughters spend endless hours on the violin and piano. Playing an instrument may improve attention, working memory and self-control.

Some of the research providing such findings comes from a group of neuroscientists led by Nina Kraus of Northwestern University. Kraus, head of the Auditory Neuroscience Laboratory there, grew up with a diverse soundscape at home. Her mother, a classical musician, spoke to the future neuroscientist in her native Italian, and Kraus still plays the piano, guitar and drums. "I love it—it's a big part of my life," she says, although she considers herself "just a hack musician."

Kraus has used EEG recordings to measure how the nervous system encodes pitch, timing and timbre of musical compositions—and whether neural changes that result from practicing music improve cognitive faculties. Her lab has found that music training enhances working memory and, perhaps most important, makes students better listeners, allowing them to extract speech from the all-talking-at-once atmosphere that sometimes prevails in the classroom.

Musical training as brain tonic is still in its infancy, and a number of questions remain unanswered about exactly what type of practice enhances executive function: Does it matter whether you play the piano or guitar or whether the music was written by Mozart or Justin Bieber? Critically, will music classes help students who have learning difficulties or who come from low-income school districts?

But Kraus points to anecdotal evidence suggesting that music training's impact extends even to academic classes. The Harmony Project provides music education to low-income youngsters in Los Angeles. Dozens of students participating in the project have graduated from high school and gone on to college, usually the first in their family to do so.

Kraus has worked with the Harmony Project and published a study in 2014 that showed that children in one of its programs who practiced a musical instrument for two years could process sounds closely linked to reading and language skills better than children who only did so for a year. Kraus is an advocate of the guitar over brain games. "If students have to choose how to spend their time between a computer game that supposedly boosts memory or a musical instrument, there's no question, in my mind, which one is more beneficial for the nervous system," Kraus says. "If you're trying to copy a guitar lead, you have to keep it in your head and try to reproduce it over and over."

HYPE ALERT

As research continues on the brain mechanisms underlying success in the "four Rs," three traditional ones (reading, writing and arithmetic) with regulation of one's impulses as the fourth, many scientists involved with neuroeducation are taking pains to avoid overhyping the interventions they are testing. They are eager to translate their findings into practical assistance for children, but they are also well aware that the research still has a long way to go. They know, too, that teachers and parents are already bombarded by a confusing raft of untested products for enhancing learning and that some highly touted tools have proved to be disappointing.

In one case in point, a small industry developed several years ago around the idea that just listening to a Mozart sonata could make a baby smarter, a contention that failed to withstand additional scrutiny. Kraus's research suggests that to gain any benefit, you have to actually play an instrument, exercising auditory-processing areas of the brain: the more you practice, the more your abilities to distinguish subtleties in sound develop. Listening alone is not sufficient.

Similarly, even some of the brain-training techniques that claim to have solid scientific proof of their effectiveness have been questioned. A meta-analysis that appeared in the March 2011 issue of the *Journal of Child Psychology and Psychiatry* reviewed studies of perhaps the best known of all brain-training methods—software called Fast ForWord, developed by Paula A. Tallal of Rutgers, Michael Merzenich of the University of California, San Francisco, and their colleagues. The analysis found no evidence of effectiveness in helping children with language or reading difficulties. As with the methods used by Benasich, a former postdoctoral fellow with Tallal, the software attempts to improve deficits in the processing of sound that can lead to learning problems. The meta-analysis provoked a sharp rebuttal from Scientific Learning, the maker of the software, which claimed that the selection criteria were too restrictive, that most studies in the analysis were poorly implemented and that the software has been improved since the studies were conducted.

The clichéd refrain—more research is needed—applies broadly to many endeavors in neuroeducation. Dehaene's number game still needs fine adjustments before it receives wide acceptance. One controlled study showed that the game helped children compare numbers, although that achievement did not carry over into better counting or arithmetic skills. A new version is being released that the researchers hope will address these problems. Yet another finding has questioned whether music training improves executive function and thereby enhances intelligence.

In a nascent field, one study often contradicts another, only to be followed by a third that disputes the first two. This zigzag trajectory underlies all of science and at times leads to overreaching claims. In neuroeducation, teachers and parents have sometimes become the victims of advertising for "science-based" software and educational programs. "It's confusing. It's bewildering," says Deborah Rebhuhn, a math teacher at the Center School, a special-education institution in Highland Park, N.J., that accepts students from public schools statewide. "I don't know which thing to try. And there's

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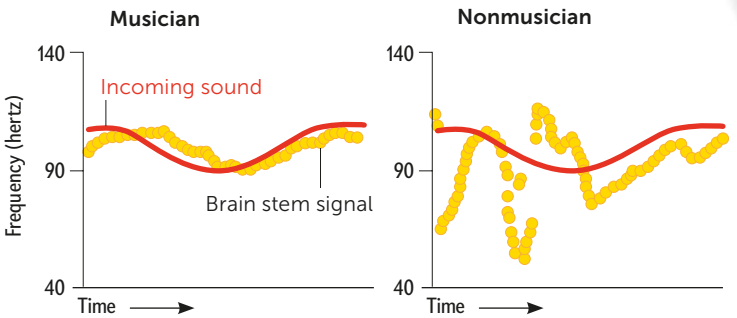
ILLUSTRATION BY BRYAN CHRISTIE, GRAPHICS BY JEN CHRISTIANSEN; SOURCE: "MUSICAL EXPERIENCE SHAPES HUMAN BRAINSTEM ENCODING OF LINGUISTIC PITCH PATTERNS," BY PATRICK C. M. WONG, ERIKA SKOE, NICOLE M. RUSSO, TASHA DEES AND NINA KRAUS, IN *NATURE NEUROSCIENCE*, VOL. 10, NO. 4; APRIL 2007 (*graphs*)

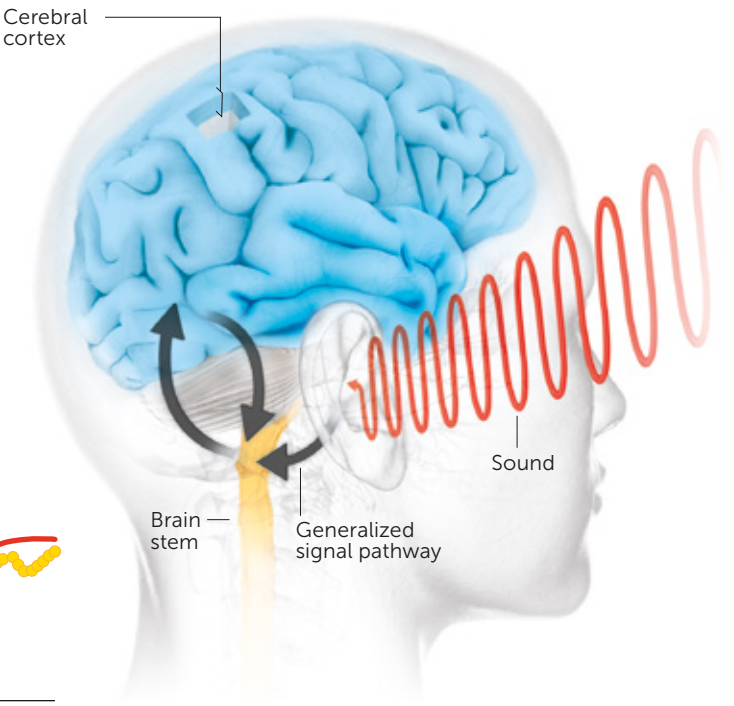
The Best Brain Training: Practice That Violin

Intensive musical training from a young age fosters skills beyond just an ability to play an instrument. The musician's concentration on the fine-grained acoustics of sound helps with language comprehension and promotes cognitive skills: attention, working memory and self-regulation.

BETTER LISTENERS

Musicians perceive sound more clearly than nonmusicians because practicing an instrument trains the entire brain. The sounds of an instrument travel from the cochlea in the inner ear to the primitive brain stem before moving to the cortex, a locus of high-level brain functions, and then back again to the brain stem and cochlea. This feedback loop allows the musician to recruit various brain areas to produce, say, the proper pitch for a tune. Monitoring of an electrical signal in the brain stem (*yellow graph line*) reveals the musician's exquisite sensitivity to pitch: the musician tracks an incoming sound wave (*red graph line*) more accurately than a nonmusician does.





not enough evidence to go to the head of the school and say that something works."

A PRESCHOOL TUNE-UP

Scientists who spend their days mulling over EEG wave forms and complex digital patterns in magnetic resonance imaging realize that they cannot yet offer definitive neuroscience-based prescriptions for improving learning. The work, however, is leading to a vision of what is possible, perhaps for Generation Z or its progeny. Consider the viewpoint of John D. E. Gabrieli, a professor of neuroscience participating in a collaborative program between Harvard University and the Massachusetts Institute of Technology. In a review article in 2009 in *Science*, Gabrieli conjectured that eventually brain-based evaluation methods, combined with traditional testing, family history and perhaps genetic tests, could detect reading problems by age six and allow for intensive early intervention that might eliminate many dyslexia cases among school-aged children.

One study has already found that EEGs in kindergartners predict reading ability in fifth graders better than standard psychological measures. By undergoing brain monitoring combined with standard methods, each child might be evaluated before entering school and, if warranted, be given remedial training based on the findings that are trickling in today from neuroscience labs. If Gabrieli's vision comes to pass, brain science may imbue the notion of individualized education with a whole new meaning—one that involves enhancing the ability to learn even before a child steps foot in the classroom. M

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RAISE GREAT KIDS

TREATING A TOXIN TO LEARNING

By
Clancy Blair

Stress may be silently sabotaging success in school. Its effects are especially potent for children in poverty

Stress can be toxic at any age. It rattles us when it strikes, shaking up our relationships and narrowing our focus. When it becomes chronic, it ravages our health. Physically, emotionally and intellectually, stress can drag us down.

An even more insidious effect is the assault it can launch on a child's brain, impeding the development of critical cognitive skills. A number of researchers, including myself, have discovered that psychological stress affects the thinking skills and brain development of even very young children, likely beginning prenatally. It is no mystery that stress thrives in difficult situations, but research is now showing that a disadvantaged upbringing may set back children in profound ways. In fact, stress may be one important mechanism through which poverty adversely affects children's ability to perform well in school.

Although children differ in their susceptibility to the problems of poverty, data show that youngsters from lower-income households are very likely to start school behind their more affluent peers. This socioeconomic gap persists throughout the school years and is difficult to close. People have long argued that disadvantaged homes tend to offer an impoverished learning environment that does not sufficiently prepare children for the rigors of school. This theory is, at best, only half of the story. My work suggests that the stresses that accompany low income—such as crowded conditions, noise, financial worries and an inability to provide adequate child care—directly impair specific learning abilities in children.

A stressful childhood may emerge from conditions other than poverty, whether from challenging family circumstances such as a divorce or death, overbearing or distracted parents, or any factors at home or at school that create anxiety. A focus on reducing stress through changes in the home or in the classroom could improve the well-being of large numbers of schoolchildren and set them up for greater success throughout life.

FLOODING THE ENGINES

Stress hormones can shape the developing circuitry of the brain. Most notably, they influence the neural connections in the prefrontal cortex, located behind the forehead, that buttress what are known as executive functions. These include the ability to hold information in mind (working memory) and to inhibit automatic or impulsive responses to stimulation. Executive functions are critical for reasoning, planning and problem solving and for regulating emotions and attention. They are essential to academic success.

The effects of stress on the brain depend on how much of it is present. A little stress heightens alertness; it improves people's performance on complex tasks. But as the dose exceeds a certain level, stress starts to erode performance. This relation between arousal and performance can be expressed as an inverted U-shaped curve, first identified by psychologists Robert Yerkes and John Dodson in 1908. In the brain, moderate amounts of stress hormones such as cortisol and noradrenaline boost activity in prefrontal areas that underlie executive functions. At high levels, however, they flood this engine of self-regulation, shutting it down. Over time the brain circuits that control stress hormone levels are shaped by experience toward a tendency to unleash either very large or very small amounts of these hormones onto the prefrontal cortex in response to stress or to maintain a more optimal level of arousal.

In 2001 I began to wonder how this physiology played out in the brains of young children and whether it might explain how poverty "gets under the skin." I set out to explore whether the chronic stress of poverty might be impairing the developing executive function of children enough to set them back at school.

THE AUTHOR

CLANCY BLAIR is professor of applied psychology at New York University, where he studies the development of self-regulation in early childhood. He earned his Ph.D. in 1996 from the University of Alabama at Birmingham. His research is supported by the National Institutes of Health.

My graduate student at the time, Rachel Peters, and I, then at Pennsylvania State University, gave two tests to 170 four-year-olds in central Pennsylvania enrolled in Head Start, the federal preschool program for children in poverty. We measured mental flexibility by asking children to identify different ways in which small groups of objects were similar. We examined working memory and inhibitory control by asking them to tap a peg twice when the experimenter tapped it once, and vice versa. Here the child has to remember the rule and control the impulse to copy the experimenter. We also asked teachers to rate each child's behavior and academic abilities. And in collaboration with neuroendocrinologist Douglas Granger, also then at Penn State, we took samples of the children's saliva to determine levels of cortisol at the beginning, middle and end of our experimental session.

The children with better executive function and behavior had low cortisol at the beginning of the session that rose and then returned to baseline, as expected, in response to the mild stress of meeting one of us and participating in our tasks. Those who showed either a sustained high level of cortisol or a blunted response—high initial levels, which then dropped, indicating a shutting down of the process—tended to have low executive function; their teachers also rated them as more aggressive and lacking in self-control. We published these results in 2005.

A little stress heightens alertness; it improves people's performance on complex tasks. But as the dose exceeds a certain level, stress starts to erode performance.

As we followed these children into kindergarten, we observed that executive function matters for achievement: this suite of mental skills was the main determinant of math proficiency, far outweighing other aspects of intelligence. And an analysis published in 2012 by our team, led by then postdoctoral researcher Daniel Berry, found that elevated cortisol in children predicts academic difficulties, as indicated by knowledge of math, letters and words. Our analysis indicated that this effect occurs through detriments to executive function—as opposed to, say, low general mental ability—demonstrating that these thinking skills are the critical link tying high cortisol to low academic ability.

POSITIVE PARENTING

Meanwhile my colleagues and I also set out to determine what aspects of poverty might contribute most to children's

FAST FACTS

RELAX TO LEARN

1. Psychological stress affects even very young children and can substantially shape the course of their cognitive, social and emotional development.
2. Stresses that accompany low income directly impair specific learning abilities in children, potentially setting them back in many domains of life.
3. Children from more affluent backgrounds can also encounter stressful situations that weaken their capacity to learn. Reducing stress in young people could improve the well-being and cognitive performance of large numbers of schoolchildren.

Children whose parents encourage them to learn by doing are calmer and more attentive than those whose mothers and fathers typically restrict them or do things for them.

stress. We focused on parenting style. Because of the stressful circumstances in which they find themselves, parents in poverty tend to elicit obedience through discipline rather than encouraging exploration and learning by doing. The latter approach, known as scaffolding, is essential to sensitive parenting. In this type of parenting, mothers and fathers interact with their children during play and create opportunities for them to accomplish small tasks, such as stacking blocks. Although impoverished parents can and do provide sensitive care, they are less likely to do so, given the realities of their situation and, potentially, their own high stress levels.

To investigate further, we have been following 1,292 children, starting at birth, and their families, most of whom live in poverty in rural communities in Appalachia and the Deep South. For about 10 years now our team has been visiting these homes annually to collect data on family and economic conditions, as well as on executive function and cortisol levels. My colleagues Martha Cox and Roger Mills-Koonce of the University of North Carolina at Chapel Hill analyzed video recordings of mothers interacting with their children in free play. In our first analysis, published in 2008, we found that infants whose mothers displayed the sensitive, scaffolding parenting style had lower cortisol levels and were calmer and more attentive than those whose mothers either completed the activity for them or restricted their attempts to do so.

Furthermore, at age seven months the children whose parents displayed the positive parenting style were more likely to exhibit a healthy cortisol response—a rise and fall—to fear (triggered by an experimenter in a mask) and frustration from a toy placed just out of reach. At age 15 months these children again had lower cortisol levels and were more likely to respond appropriately to the emotional challenges. We now had evidence that parenting style shapes the developing stress-response system.

We next sought to sketch the complete path from poverty to parenting to increased stress and diminished executive function in the same group of children. Most recently, we found that the more severely impoverished the family, the less likely parents were to be sensitive and responsive. As expected, the children in such homes had elevated cortisol, which was, in turn, associated with lower executive function. We also saw that less positive parenting went hand in hand with poorer executive function in children, indicating that mothers and fathers can directly stimulate the development of important mental skills.

CREATING CAPABLE KIDS

Research indicates that stress from a variety of sources—chaotic and poorly run classrooms, for example, or problems with family or peers—impedes learning. The potential good news: knowing that stress is a malevolent force means that finding ways to thwart it could boost children's learning capacity.

In that vein, my collaborators and I are testing a program that teaches parents how to be more sensitive and how to structure opportunities for their children to learn while providing warm and loving care. We have also shown that an innovative curriculum that gives kindergarteners and preschoolers more control over their learning activities has large effects on learning and executive functions for children in high-poverty schools. Although this work is in its early stages, we are encouraged by the possibility that informed changes to environments can boost children's self-control and academic competence, giving many of our youth a far greater chance of succeeding in life. **M**

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A NEW VISION FOR TESTING

By
Annie Murphy Paul

Too often school assessments heighten anxiety and hinder learning. New research shows how to reverse the trend

Illustrations by
Mario Wagner

Who was the first American to orbit Earth?

A NEIL ARMSTRONG

B YURI GAGARIN

C JOHN GLENN

D NIKITA KHRUSHCHEV

In schools across the U.S., multiple-choice questions such as this one provoke anxiety, even dread. Their appearance means it is testing time, and tests are big, important, excruciatingly unpleasant events.

But not at Columbia Middle School in Illinois, in the classroom of eighth grade history teacher Patrice Bain. Bain has lively blue eyes, a quick smile, and spiky platinum hair that looks punkish and pixieish at the same time. After displaying the question on a smartboard, she pauses as her students enter their responses on numbered devices known as clickers.

"Okay, has everyone put in their answers?" she asks. "Number 19, we're waiting on you!" Hurriedly, 19 punches in a selection, and together Bain and her students look over the class's responses, which are now displayed at the bottom of the smartboard screen. "Most of you got it—John Glenn—very nice." She chuckles and shakes her head at the answer three of her students have submitted. "Oh, my darlings," says Bain in playful reproach. "Khrushchev was *not* an astronaut!"

Bain moves on to the next question, briskly repeating the process of asking, answering and explaining as she and her students work through the decade of the 1960s.

The failed Bay of Pigs invasion involved the United States and which country?

A HONDURAS

B HAITI

C CUBA

D GUATEMALA

When every student gives the correct answer, the class members raise their hands and wiggle their fingers in unison, an exuberant gesture they call "spirit fingers." This is the case with the Bay of Pigs question: every student nails it.

"All right!" Bain enthuses. "That's our fifth spirit fingers today!"

The banter in Bain's classroom is a world away from the tense standoffs at public schools around the country. Since the enactment of No Child Left Behind in 2002, parents' and teachers' opposition to the law's mandate to test "every child, every year" in grades three through eight has steadily intensified. A growing number of parents are withdrawing

FAST FACTS

THE TESTING EFFECT

1. Since the enactment of No Child Left Behind in 2002, parents' and teachers' opposition to the law's mandate to test "every child, every year" in grades three through eight has intensified.
2. Critics charge that the high-stakes assessments inflict anxiety on students and teachers, turning classrooms into test-preparation factories instead of laboratories of meaningful learning.
3. Research in cognitive science and psychology shows that testing, done right, can be an effective way to learn—producing better recall of facts and deeper understanding.
4. Tests being developed to assess how well students have met the Common Core State Standards show promise as evaluations of deep learning.

their children from the annual state tests; the epicenter of the "opt-out" movement may be New York State, where almost 90 percent of students in some districts are reported to have refused to take the yearly examination in the spring of 2015. Critics of U.S. schools' heavy emphasis on testing charge that the high-stakes assessments inflict anxiety on students and teachers, turning classrooms into test-preparation factories instead of laboratories of genuine, meaningful learning.

In the always polarizing debate over how American students should be educated, testing has become the most controversial issue of all. In fact, in response to long-standing bipartisan opposition to No Child Left Behind, at the end of 2015 Congress enacted a law repealing most of the federal influence over education that the No Child policy had established. Yet a crucial piece has been largely missing from the discussion so far. Research in cognitive science and psychology shows that testing, done right, can be an exceptionally effective way to learn. Taking tests, as well as engaging in well-designed activities before and after tests, can produce better recall of facts—and deeper and more complex understanding—than an education without exams. But a testing regime that actively supports learning, in addition to simply assessing, would look very different from the way American schools "do" testing today.

What Bain is doing in her classroom is called retrieval practice. The practice has a well-established base of empirical support in the academic literature, going back almost 100 years—but Bain, unaware of this research, worked out something very similar on her own over the course of more than two decades in the classroom.

"I've been told I'm a wonderful teacher, which is nice to hear, but at the same time I feel the need to tell people: 'No, it's not me—it's the method,'" says Bain in an interview after her class has ended. "I've seen it work such wonders that I want to get up on a mountaintop and shout so everyone can hear me: 'You should be doing this, too!' But it's been hard to persuade other teachers to try it."

Then, nine years ago, she met Mark McDaniel through a mutual acquaintance. McDaniel is a psychology professor at Washington University in St. Louis, a half an hour's drive from Bain's school. McDaniel had started to describe to Bain his research on retrieval practice when she broke in with an exclamation. "Patrice said, 'I do that in my classroom! It works!'" McDaniel recalls. He went on to explain to Bain that what he and his colleagues refer to as retrieval practice is, essentially, testing. "We used to call it 'the testing effect' until we got smart and realized that no teacher or parent would want to touch a technique that had the word 'test' in it," McDaniel notes now.

Retrieval practice does not use testing as a tool of assessment. Rather it treats tests as occasions for learning, which makes sense only once we recognize that we have misunderstood the nature of testing. We think of tests as a kind of dipstick that we insert into a student's head, an indicator that tells us how high the level of knowledge has risen in there—when in fact, every time a student calls up knowledge from memory, that memory *changes*. Its mental representation becomes stronger, more stable and more accessible.

Why would this be? It makes sense considering that we could not possibly remember everything we encounter, says Jeffrey D. Karpicke, a professor of cognitive psychology at Purdue University. Given that our memory is necessarily selective, the usefulness of a fact or idea—as demonstrated by how often we have had reason to recall it—makes a sound

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basis for selection. "Our minds are sensitive to the likelihood that we'll need knowledge at a future time, and if we retrieve a piece of information now, there's a good chance we'll need it again," Karpicke explains. "The process of retrieving a memory alters that memory in anticipation of demands we may encounter in the future."

Studies employing functional magnetic resonance imaging (fMRI) of the brain are beginning to reveal the neural mechanisms behind the testing effect. In the handful of studies that have been conducted so far, scientists have found that calling up information from memory, as compared with simply restudying it, produces higher levels of activity in particular areas of the brain. These brain regions are associated with the so-called consolidation, or stabilization, of memories and with the generation of cues that make memories readily accessible later on. Across several studies, researchers have demonstrated that the more active these regions are during an initial learning session, the more successful is study participants' recall weeks or months later.

According to Karpicke, retrieval is the principal way learning happens. "Recalling information we've already stored in memory is a more powerful learning event than storing that information in the first place," he says. "Retrieval is ultimately the process that makes new memories stick." Not only does retrieval practice help students remember the specific information they retrieved, it also improves retention for related information that was not directly tested.

Researchers theorize that while sifting through our mind for the particular piece of information we are trying to recollect, we call up associated memories and in so doing strengthen them as well. Retrieval practice also helps to prevent students from confusing the material they are currently learning with material they learned previously, and it even appears to prepare students' minds to absorb the material still more thoroughly when they encounter it again after testing (a phenomenon that researchers call test-potentiated learning).

Hundreds of studies have demonstrated that retrieval practice is better at improving retention than just about any other method learners could use. To cite one example: in a study published in 2008 by Karpicke and his mentor, Henry L. Roediger III of Washington University, the authors reported that students who quizzed themselves on vocabulary terms remembered 80 percent of the words later on, whereas students who studied the words by repeatedly reading them over remembered only about a third of the words. Retrieval practice is especially powerful compared with students' most favored study strategies: highlighting and rereading their notes and textbooks, practices that a recent review found to be among the *least* effective.

And testing does not merely enhance the recall of isolated facts. The process of pulling up information from memory also fosters what researchers call deep learning. Students engaging in deep learning are able to draw inferences from, and make connections among, the facts they know and are able to apply their knowledge in varied contexts—a process learning scientists refer to as transfer. In an article published in 2011 in the journal *Science,* Karpicke and his Purdue colleague Janell Blunt explicitly compared retrieval practice with a study technique known as concept mapping. An activity favored by many teachers as a way to promote deep learning, concept mapping asks students to draw a diagram that depicts the body of knowledge they are learning, with the relations among concepts represented by links among nodes, like roads linking cities on a map.

In their study, Karpicke and Blunt directed groups of undergraduate volunteers—200 in all—to read a passage taken from a science textbook. One group was then asked to create a concept map while referring to the text; another group was asked to recall, from memory, as much information as they could from the text they had just read. On a test given to all the students a week later, the retrieval-practice group was better able to recall the concepts presented in the text than was the concept-mapping group. More striking, the former group was also better able to draw inferences and make connections among multiple concepts contained in the text. Overall, Karpicke and Blunt concluded, retrieval practice was about 50 percent more effective at promoting both factual and deep learning.

Transfer—the ability to take knowledge learned in one context and apply it to another—is the ultimate goal of deep learning. In an article published in 2010, University of Texas at Austin psychologist Andrew Butler demonstrated that retrieval practice promotes transfer better than the conventional approach of studying by rereading. In Butler's experiment, students engaged either in rereading or in retrieval practice after reading a text that pertained to one "knowledge domain"—in this case, bats' use of sound waves to find their way around. A week later the students were asked to transfer what they had learned about bats to a second knowledge domain: the navigational use of sound waves by submarines. Students who had quizzed themselves on the original text about bats were better able to transfer their learning about bats to submarines.

REAL-WORLD EVIDENCE

Robust though such findings are, they were until recently almost exclusively made in the laboratory, with college students as subjects. McDaniel had long wanted to apply retrieval practice in real-world schools, but gaining access to K–12 classrooms was a challenge. With Bain's help, McDaniel and two of his Washington University colleagues, Roediger and Kathleen McDermott, set up a randomized controlled trial at Columbia Middle School that ultimately involved nine teachers and more than 1,400 students. During the course of the experiment, sixth, seventh and eighth graders learned about science and social studies in one of two ways: 1) material was presented once, then teachers reviewed it with students three times; 2) material was presented once, and stu-

dents were quizzed on it three times (using clickers like the ones in Bain's current classroom).

When the results of students' regular unit tests were calculated, the difference between the two approaches was clear: students earned an average grade of C+ on material that had been reviewed and A– on material that had been quizzed. On a follow-up test administered eight months later, students still remembered the information they had been quizzed on much better than the information they had reviewed.

"I had always thought of tests as a way to assess—not as a way to learn—so initially I was skeptical," says Andria Matzenbacher, a former teacher at Columbia who now works as an instructional designer. "But I was blown away by the difference retrieval practice made in the students' performance." Bain, for one, was not surprised. "I knew that this method works, but it was good to see it proven scientifically," she says. McDaniel, Roediger and McDermott eventually extended the study to nearby Columbia High School, where quizzing generated similarly impressive results. In an effort to make retrieval practice a common strategy in classrooms across the country, the Washington University team developed a manual for teachers, *How to Use Retrieval Practice to Improve Learning*.

Even with the weight of evidence behind them, however, advocates of retrieval practice must still contend with a reflexively negative reaction to testing among many teachers and parents. They also encounter a more thoughtful objection, which goes something like this: American students are tested so much already—far more often than students in other countries, such as Finland and Singapore, which regularly place well ahead of the U.S. in international evaluations. If testing is such a great way to learn, why aren't our students doing better?

Marsha Lovett has a ready answer to that question. Lovett, director of the Eberly Center for Teaching Excellence and Educational Innovation at Carnegie Mellon University, is an expert on "metacognition"—the capacity to think about our own learning, to be aware of what we know and do not know, and to use that awareness to effectively manage the learning process.

Yes, Lovett says, American students take a lot of tests. It is what happens afterward—or more precisely, what *does not* happen—that causes these tests to fail to function as learning opportunities. Students often receive little information about what they got right and what they got wrong. "That kind of item-by-item feedback is essential to learning, and we're throwing that learning opportunity away," she says. In addition, students are rarely prompted to reflect in a big-picture way on their preparation for, and performance on, the test. "Often students just glance at the grade and then stuff the test away somewhere and never look at it again," Lovett says. "Again, that's a really important learning opportunity that we're letting go to waste."

A few years ago Lovett came up with a way to get students to engage in reflection after a test. She calls it an "exam wrapper." When the instructor hands back a graded test to a student, along with it comes a piece of paper literally wrapped around the test itself. On this paper is a list of questions: a short exercise that students are expected to complete and hand in. The wrapper that Lovett designed for a math exam includes such questions as:

How much time did you spend reviewing with each of the following:

- Reading class notes? ___ minutes
- Reworking old homework problems? ___ minutes
- Working additional problems? ___ minutes
- Reading the book? ___ minutes

Now that you have looked over your exam, estimate the percentage of points you lost due to each of the following:

- ___ % from not understanding a concept
- ___ % from not being careful (*i.e., careless mistakes*)
- ___ % from not being able to formulate an approach to a problem
- ___ % from other reasons (*please specify*)

Based on the estimates above, what will you do differently in preparing for the next test? For example, will you change your study habits or try to sharpen specific skills? Please be specific. Also, what can we do to help?

The idea, Lovett says, is to get students thinking about what they did not know or did not understand, why they failed to grasp this information and how they could prepare more effectively in advance of the next test. Lovett has been promoting the use of exam wrappers to the Carnegie Mellon faculty for several years now, and a number of professors, especially in the sciences, have incorporated the technique into their courses. They hand out exam wrappers with graded exams, collect the wrappers once they are completed, and—cleverest of all—they hand back the wrappers at the time when students are preparing for the next test.

Does this practice make a difference? In 2013 Lovett published a study of exam wrappers as a chapter in the edited volume *Using Reflection and Metacognition to Improve Student Learning*. It reported that the metacognitive skills of students in classes that used exam wrappers increased more across the semester than those of students in courses that did not employ exam wrappers. In addition, an end-of-semester survey found that among students who were given exam wrappers, more than half cited specific changes they had made in their approach to learning and studying as a result of filling out the wrapper.

The practice of using exam wrappers is beginning to spread to other universities and to K–12 schools. Lorie Xikes teaches at Riverdale High School

in Fort Myers, Fla., and has used exam wrappers in her AP Biology class. When she hands back graded tests, the exam wrapper includes such questions as:

Approximately how much time did you spend preparing for the test? (Be honest.)

Was the TV/radio/computer on? Were you on any social media site while studying? Were you playing video games? (Be honest.)

Now that you have looked over the test, check the following areas that you had a hard time with:

- Applying definitions ___
- Lack of understanding concepts ___
- Careless mistakes ___
- Reading a chart or graph ___

Based on your responses to the questions above, name at least three things you will do differently in preparing for the next test. Be specific.

"Students usually just want to know their grade, and that's it," Xikes says. "Having them fill out the exam wrapper makes them stop and think about how they go about getting ready for a test and whether their approach is working for them or not."

In addition to distributing exam wrappers, Xikes also devotes class time to going over the graded exam, question by question—feedback that helps students develop the crucial capacity of "metacognitive monitoring," that is, keeping tabs on what they know and what they still need to learn. Research on retrieval practice shows that testing can identify specific gaps in students' knowledge, as well as puncture the general overconfidence to which students are susceptible—but only if prompt feedback is provided as a corrective.

Over time, repeated exposure to this testing-feedback loop can motivate students to develop the ability to monitor their own mental processes. Affluent students who receive a top-notch education may acquire this skill as a matter of course, but this capacity is often lacking among low-income students who attend struggling schools—holding out the hopeful possibility that retrieval practice could actually begin to close achievement gaps between the advantaged and the underprivileged.

This is just what James Pennebaker and Samuel Gosling, professors at the University of Texas at Austin, found when they instituted daily quizzes in the large psychology course they teach together. The quizzes were given online, using software that informed students whether they had responded correctly to a question immediately after they submitted an answer. The grades earned by the 901 students in the course featuring daily quizzes were, on average, about half a letter grade higher than those earned by a comparison group of 935 of Pennebaker and Gosling's previous students, who had experienced a more traditionally designed course covering the same material.

Astonishingly, students who took the daily quizzes in their psychology class also performed better in their *other* courses, during the semester they were enrolled in Pennebaker and Gosling's class and in the semesters that followed—suggesting that the frequent tests accompanied by feedback worked to improve their general skills of self-regulation. Most exciting to the professors, the daily quizzes led to a 50 percent reduction in the achievement gap, as measured by grades, among students of different social classes. "Repeated testing is a powerful practice that directly enhances learning and thinking skills, and it can be especially helpful to students who start off with a weaker academic background," Gosling says.

STANDARDIZED WOES

Gosling and Pennebaker, who (along with U.T. graduate student Jason Ferrell) published their findings on the effects of daily quizzes in 2013 in the journal *PLOS ONE*, credited the "rapid, targeted, and structured feedback" that students received with boosting the effectiveness of repeated testing. And therein lies a dilemma for American public school students, who take an average of 10 *standardized* tests a year in grades three through eight, according to a recent study conducted by the Center for American Progress. Unlike the instructor-written tests given by the teachers and professors profiled here, standardized tests are usually sold to schools by commercial publishing companies. Scores on these tests often arrive weeks or even months after the test is taken. And to maintain the security of test items—and to use the items again on future tests—testing firms do not offer item-by-item feedback, only a rather uninformative numerical score.

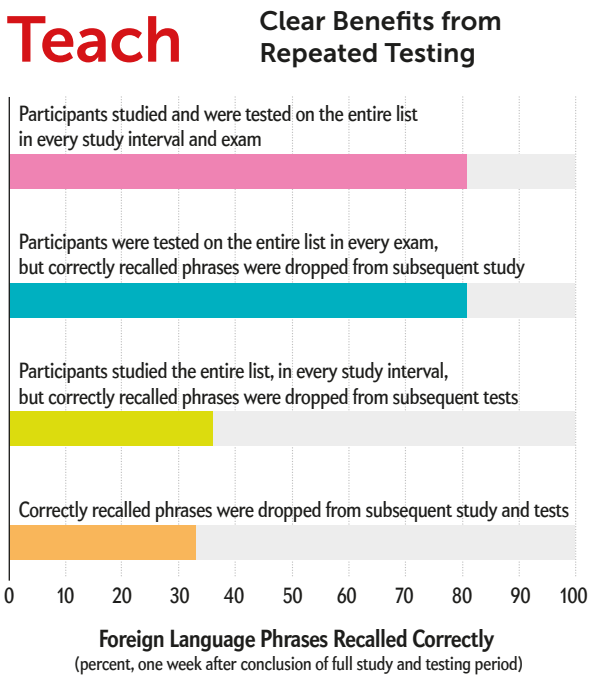
There is yet another feature of standardized state tests that prevents them from being used more effectively as occasions for learning. The questions they ask are overwhelmingly of a superficial nature—which leads, almost inevitably, to superficial learning.

If the state tests currently in use in U.S. were themselves assessed on the difficulty and depth of the questions they ask, almost all of them would flunk. That is the conclusion reached by Kun Yuan and Vi-Nhuan Le, both then behavioral scientists at RAND Corporation, a nonprofit think tank. In a report published in 2012 Yuan and Le evaluated the mathematics and English language arts tests offered by 17 states, rating each question on the tests on the cognitive challenge it poses to the test taker. The researchers used a tool called Webb's Depth of Knowledge—created by Norman Webb, a senior scientist at the Wisconsin Center for Education Research—which identifies four levels of mental rigor, from DOK1 (simple recall), to DOK2 (application of skills and concepts), through DOK3 (reasoning and inference), and DOK4 (extended planning and investigation).

Most questions on the state tests Yuan and Le examined were at level DOK1 or DOK2. The authors used level DOK4 as their benchmark for questions that measure deeper learning, and by this standard the tests are failing utterly. Only 1 to 6 percent of students were assessed

RECALL

Tests That Teach



Quizzes can do more than assess learning—they can boost it. In a study designed to compare studying versus testing, published in 2008 in the journal *Science,* psychologists asked four groups of college students to learn 40 Swahili vocabulary words. The first group studied the words and was repeatedly tested on them. Other groups dropped the words they had memorized from subsequent study or testing, or both. One week later students who were repeatedly quizzed on all the words remembered 80 percent, whereas students who only studied the words remembered about a third.

on deeper learning in reading through state tests, Yuan and Le report; 2 to 3 percent were assessed on deeper learning in writing; and *0* percent were assessed on deeper learning in mathematics. "What tests measure matters because what's on the tests tends to drive instruction," observes Linda Darling-Hammond, emeritus professor at the Stanford Graduate School of Education and a national authority on learning and assessment. That is especially true, she notes, when rewards and punishments are attached to the outcomes of the tests, as with the No Child Left Behind law, and states' own "accountability" measures.

According to Darling-Hammond, the provisions of No Child Left Behind effectively forced states to employ inexpensive, multiple-choice tests that could be scored by machine—and it is all but impossible, she contends, for such tests to measure deep learning. But *other* kinds of tests could do so. Darling-Hammond wrote, with her Stanford colleague Frank Adamson, the 2014 book *Beyond the Bubble Test,* which describes a very different vision of assessment: tests that pose open-ended questions (the answers to which are evaluated by teachers, not machines), that call on students to develop and defend an argument, and that ask test takers to conduct a scientific experiment or construct a research report.

In the 1990s, Darling-Hammond points out, some American states had begun to administer such tests. That effort ended with the passage of No Child Left Behind. She acknowledges that the movement toward more sophisticated tests also stalled because of concerns about logistics and cost. Still, assessing students in this way is not a pie-in-the-sky fantasy: Other nations, such as England and Australia, are doing so already. "Their students are performing the work of real scientists and historians, while our students are filling in bubbles," Darling-Hammond says. "It's pitiful."

She does see some cause for optimism: A new generation of tests are being developed in the U.S. to assess how well students have met the Common Core State Standards, the set of academic benchmarks in literacy and math that have been adopted by 43 states. Two of these tests—Smarter Balanced and Partnership for Assessment of Readiness for College and Careers (PARCC)—show promise as tests of deep learning, says Darling-Hammond, pointing to a recent evaluation conducted by Joan Herman and Robert Linn, researchers at U.C.L.A.'s National Center for Research on Evaluation, Standards, and Student Testing. Herman notes that both tests intend to emphasize questions at and above level 2 on Webb's Depth of Knowledge, with at least a third of a student's total possible score coming from questions at DOK3 and DOK4. "PARCC … may not go as far as we would have liked," Herman conceded in a blog post in 2014, but "they are likely to produce a big step forward." M

SOURCE: "THE CRITICAL IMPORTANCE OF RETRIEVAL FOR LEARNING," BY JEFFREY D. KARPICKE AND HENRY L. ROEDIGER III, IN *SCIENCE,* VOL. 310; FEBRUARY 19, 2008

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RAISE GREAT KIDS

WHY JOHNNY CAN'T NAME HIS COLORS

By
Melody Dye

The way we commonly use color and number words in English makes it exceptionally tricky for kids to learn the concepts

Subject 046M, two years old, was seated nervously across from me at the table, his hands clasped tightly together in his lap. He appeared to have caught an incurable case of the squirms. I resisted the urge to laugh and leaned forward, whispering conspiratorially. "Today we're going to play a game with Mr. Moo." I produced an inviting plush cow from behind my back. "Can you say hi to Mr. Moo?"

That spring I was a newly minted researcher in the laboratory of cognitive scientist Michael Ramscar, who was then at Stanford University. Ramscar was studying how children go about what is arguably the most vital project in their schooling—learning language. We were particularly taken with the question of how kids learn a small but telling piece of that vast complex: color words. We wanted to know how much kids know, when they know it and whether we can help them get there faster.

046M ("M" for male) was off to a good start. I arranged three color swatches in front of him. "Can you show me the red one?" He paused, then pointed to the middle rectangle. "Very good!" I said, beaming. "Now, what about the one that's blue?"

The test was not designed to trip kids up. Far from it—we tested only basic color words, and we never made them pick between confusable shades, such as red and pink. To an adult, the test would be laughably easy. Yet after several months of testing two-year-olds, I could count my high scorers on one hand. Most would fail the test outright. 046M, despite his promising start, proved no exception.

There is a surprising disconnect between what children seem to know about colors and numbers and what they actually demonstrate when tested. Nailing down just what "red" or "three" means is a difficult hurdle in mastering language, and even older children sometimes slip up and reveal a less than expert grasp of these concepts. We discovered in our lab that the way we use color and number words in everyday English actually impedes kids' learning.

Parents see their children's color and number knowledge as developmental milestones for good reason—these concepts lay the foundations for key aspects of perceptual and numerical reasoning. Our research revealed that if we understand how the developing brain makes sense of speech, we can help children reach these milestones more painlessly. By phrasing things slightly differently, adults can help youngsters to grasp colors and numbers—and therefore advance to a higher understanding of language—much earlier in life.

THE AUTHOR

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GETTY IMAGES; IMAGES FOR ILLUSTRATION PURPOSES ONLY

RED APPLES, BLUE SKIES

Before each experimental session began, a research assistant would explain to the child's parents that we would be testing color words. Responses were typically enthusiastic. "Oh, that's great! Margie's got her colors down pat." At that point we leveled with them: if they wanted to be present during the study, they would have to be blindfolded. Such measures may seem extreme—but then again, so were the reactions we got from parents during the pilot study, as they watched their little ones fail to pick out the correct hue, over and over again. The reactions ran the short line from shocked to terrified and back again. Some parents were so dismayed they started impatiently correcting their children midtest. One mother, in particular, could not seem to stop herself and took to nervously grabbing her little boy's hand whenever it started to veer away from the correct choice.

Then, inevitably, came the post-test breakdown: "Is my child color-blind?"

The baffled response is not new. Charles Darwin was startled by his own children's failings when it came to color, writing in 1877: "They could not name the colors, although I tried repeatedly to teach them." About a century later developmental psychologists began to systematically determine what it was that made learning color words so hard for kids. The obvious hypotheses were soon ruled out. First, children are not color-blind. They can perceptually distinguish colors within a few months of birth. Nor do kids lack experience with color words, which are common in speech and some of the first words in their vocabularies.

A typical toddler, for example, can use colors appropriately in common phrases, such as "yellow banana," "blue sky" and "red fire truck," and can even correctly answer familiar questions such as "What color is a tomato?" This apparent mastery is why parents are so often convinced their kids are color experts. But they might be far less confident if they realized that blind children are capable of much the same feat. It turns out that kids can learn to use color words in context simply by paying attention to how things usually get talked about—for instance, the word "red" tends to come up a lot with "fire trucks" but not so much with "ice cream."

Take away that crucial context, and most two- and three-year-old kids are stumped—they cannot correctly identify colors in a lineup or accurately use color words in novel scenarios. What is more, psychologists have found that even after hours and hours of repeated training on color words, performance typically fails to improve noticeably, and children who are as old as six continue to make major errors naming colors. This last fact is seriously bizarre when you consider all the other things that children at that age can do: ride a bike, tie their shoes, read the comics and—mistake a blue cupcake for an orange one? Really?

If you say "the balloon is red," you will have helped narrow "red" to being an attribute of the balloon and not some general property of the world at large.

Really. And that is where 046M and his color-naming compatriots came in. Armed with the tools of cognitive psychology, we decided it was high time to figure out why it takes so long for children to learn colors, of all things, and whether we could shortcut the process.

THE GRASS IS GREEN

Psychologists before us have pointed out that part of what complicates color learning is that we are constantly surrounded by a vast array of hues. This overwhelming ubiquity is not a feature of other common words, such as nouns. Imagine, for example, that a child is trying to learn to distinguish "dog" from "bear." The learning problem is not so difficult in this case: unless you are watching *Old Yeller,* dogs will tend to be seen and talked about in contexts in which bears are not present, and vice versa.

Contrast this with the problem of learning color words. In most situations when a three-year-old hears "red" there will be a kaleidoscope of other colors present. Sorting out which hues are "red" and which are "orange" is much harder than figuring out which furry beasts are "bears" and which are "dogs." This may explain why children, across every language studied, invariably learn their nouns before their colors.

As it happens, English color words may be especially difficult to learn because English speakers throw in a curveball by using color words "prenominally," meaning before nouns. For instance, we will often say things like "the red balloon," instead of using the postnominal construction, "the balloon is red." Our

FAST FACTS

LEARNING COLORS

1. Surprisingly, most kids struggle with learning colors and numbers—foundational elements to developing language skills.
2. The way English speakers form sentences, by placing adjectives before nouns, can make it difficult for children to learn colors and numbers.
3. Parents can help their children learn colors by inverting the descriptions they use for colored items; for example, "the fire truck that is red," as opposed to "the red fire truck."

study set out to determine if our choice of word placement could actually influence kids' ability to learn colors.

Sentence construction matters, in theory, because of how attention works. In conversation, people have to track what is being talked about, and they often do this visually. If I were to start referring to "the old *fnord* in the corner," you would probably begin quickly glancing around for the mystery person or object.

Kids do the same thing, only more avidly, because they have much, much more to learn about. That means that when you stick the noun before the color word, you can successfully narrow their focus to whatever it is you are talking about before you hit them with the color. If you say "the balloon is red," for example, you will have helped narrow "red" to being an attribute of the balloon and not some general property of the world at large.

From what we can decipher, children also figure out that the "red" in "the red balloon" has to do with the balloon, but they interpret it differently. When we say "the balloon is red," they learn that "red" is the name of a property, such as "wet" or "sharp," whereas when we say "the red balloon," they learn that "red" is more like a proper name, such as "Tom" or "Heather." Knowing someone's name does not usually reveal as much as knowing that someone is cruel or kind. Whether kids learn "red" as something like a name or something like a property depends entirely on how their attention is directed when they hear it.

HELPING KIDS LEARN HUES

Our hypothesis was simple: using color words after nouns should make colors far easier to learn and kids far faster at learning them. To test this idea, we took a group of two-year-olds and gave them some quick training on color words. Either we trained them with prenominal sentences (the standard variety in English) or postnominal sentences (helpful, we hoped). In both cases, we would simply show them familiar objects and say encouraging things such as "this is a blue crayon" or "this crayon is yellow."

AGE FOTOSTOCK

Pass the Blue

In English, we tend to position adjectives before nouns ("the green grass"), an ordering preference that can make it harder for kids to learn their colors and numbers than if we were to reverse the sequence ("the grass is green"). Many other languages naturally use the latter construction, placing adjectives after the nouns they describe. Does that mean a child growing up in a French- or Spanish-speaking household will grasp the concept of colors more easily?

The short answer is we do not know. Elise Percy and her colleagues have found that word order biases can influence how speakers of different languages organize information in memory. But studies have not yet been done comparing color learning between prenominally biased languages and postnominally biased ones. The outcome of such a study might not be so predictable, because many of those languages come with curveballs of their own. In Spanish, for instance, speakers often omit nouns in casual conversation. Whereas English speakers will ask for the "blue bowl," Spanish speakers can just as gracefully demand "the blue." *—M.D.*

As we reported in August 2010 in *Cognitive Science*, the kids who got the postnominal training improved significantly over their baseline test scores, whereas the ones who got the prenominal training still looked just as confused as ever. Given that previous studies had not found much improvement after hundreds of explicit training trials, it was hard to believe that such a simple manipulation could make such a clear difference. And yet it did.

Next up, we ran a similar experiment using numbers instead of colors. To assess how well our young subjects understood numbers, we first asked them, "Look, hearts; can you show me four?" and "Can you show me four hearts?" We then trained the kids on number words, one group prenominally and one postnominally. Here again the sentence construction made all the difference. After only 15 minutes of training, youngsters who learned postnominally ("Flowers! There are six") dramatically improved their test scores, averaging 30 percent better in both reliability and accuracy. Those who we trained prenominally ("There are six flowers") showed no improvement.

Considering that early number comprehension is a good indicator of how well children will do in math later in life, helping kids learn numbers at a younger age could very well have a long-lasting influence. Which brings me to the key, take-home point: if you want your two-year-old to match colors with aplomb and count with ease, watch your tongue. It might seem faster to ask Johnny not to pop "the red balloon," but it may be better for him if you rephrase: "I mean, the balloon that is red." M

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THE SERIOUS NEED FOR PLAY

RAISE GREAT KIDS

Free, imaginative play is crucial for normal social, emotional and cognitive development. It makes us better adjusted, smarter and less stressed

PLAY

By
Melinda Wenner Moyer

Photograph By
Aaron Goodman

On August 1, 1966,

the day psychiatrist Stuart Brown started his assistant professorship at the Baylor College of Medicine in Houston, 25-year-old Charles Whitman climbed to the top of the University of Texas Tower on the Austin campus and shot 46 people. Whitman, an engineering student and a former U.S. Marine sharpshooter, was the last person anyone expected to go on a killing spree. After Brown was assigned as the state's consulting psychiatrist to investigate the incident and later, when he interviewed 26 convicted Texas murderers for a pilot study, he discovered that most of the killers, including Whitman, shared two things in common: they were from abusive families, and they never played as kids.

Brown did not know which factor was more important. But in the nearly 50 years since, he has interviewed more than 6,000 people about their childhoods, and his data suggest that a lack of opportunities for unstructured, imaginative play can keep children from growing into happy, well-adjusted adults. "Free play," as scientists call it, is critical for becoming socially adept, coping with stress and building cognitive skills such as problem solving. Research into animal behavior confirms play's benefits and establishes its evolutionary importance.

Most psychologists agree that play affords benefits that last through adulthood, but they do not always agree on the extent to which a lack of play harms kids—particularly because, in the past, few children grew up without ample frolicking time. But today free play may be losing its standing as a staple of youth. According to a paper published in 2005

When animals play, their body language signals that any nipping or tumbling is meant to be friendly and fun. Play similarly teaches kids to better communicate with one another.

in the *Archives of Pediatrics & Adolescent Medicine,* children's free-play time dropped by a quarter between 1981 and 1997. Concerned about getting their kids into the right colleges, parents are sacrificing playtime for more structured activities. As early as preschool, youngsters' after-school hours are now being filled with music lessons and sports—reducing time for the type of imaginative and rambunctious cavorting that fosters creativity and cooperation. Free play has been sacrificed at school, too. According to a 2007 survey conducted by the Center on Education Policy, 20 percent of 349 American elementary public school districts had decreased their recess time since 2001.

A handful of studies have supported Brown's conviction that a play-deprived childhood disrupts normal social, emotional and cognitive development in humans and animals. He and other psychologists worry that limiting free play in kids may result in a generation of anxious, unhappy and socially maladjusted adults. "The consequence of a life that is seriously play-deprived is serious stuff," Brown says. But it is never too late to start: play also promotes the continued mental and physical well-being of adults [*see box on page 55*].

Worries over the demise of play began surfacing as far back as 1961, when the International Play Association was founded in Denmark to protect, preserve and promote play as a fundamental right for all children. But the idea became more popular in the past few decades, when many more nonprofit foundations—such as the National Institute for Play in Carmel Valley, Calif., started by Brown, and other organizations, including the Alliance for Childhood and the Association for the Study of Play—began forming to promote the value of play.

FREEDOM COUNTS

But kids *play* soccer, Scrabble and the sousaphone—so why are experts concerned that these activities are eating into free play? Certainly games with rules are fun and are sources of learning experiences—they may indeed foster better social skills and group cohesion, for instance, says Anthony D. Pellegrini, an educational psychologist at the University of Minnesota. But, Pellegrini explains, "games have a priori rules—set up in advance and followed. Play, on the other hand, does not have a priori rules,

FAST FACTS

GO AHEAD, HORSE AROUND

1. Childhood play is crucial for social, emotional and cognitive development.
2. Imaginative and rambunctious "free play," as opposed to games or structured activities, is the most essential type.
3. Kids and animals that do not play when they are young may grow into anxious, socially maladjusted adults.

JUPITERIMAGES

Dressing up and pretending to be someone else is a type of "free play," as psychologists call it—the unstructured, imaginative fun that is most challenging to the developing brain.

JUPITERIMAGES (*top*); GHISLAIN & MARIE DAVID DE LOSSY *Getty Images* (*bottom*)

THE AUTHOR

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so it affords more creative responses."

This creative aspect is key because it challenges the developing brain more than following predetermined rules does. In free play, kids initiate and create new activities and roles. It might involve fantasies—such as pretending to be doctors or princesses—or it might include mock fighting, as when kids (primarily boys) wrestle with one another for fun, switching roles periodically so that neither of them always wins. And free play is most similar to play seen in the animal kingdom, suggesting that it has important evolutionary roots. Gordon M. Burghardt, author of the 2005 *The Genesis of Animal Play*, spent 18 years observing animals to learn how to define play: it must be repetitive—an animal that nudges a new object just once is not playing with it—and it must be voluntary and initiated in a relaxed setting. Animals and children do not play when they are undernourished or in stressful situations. Most essential, the activity should not have an obvious function in the context in which it is seen—meaning that it has no clear goal.

FACE TIME

How do these seemingly pointless activities benefit kids? Perhaps most crucially, play appears to help us develop strong social skills. "You don't become socially competent via teachers telling you how to behave," Pellegrini says. "You learn those skills by interacting with your peers, learning what's acceptable, what's not acceptable." Children learn to be fair and take turns—they cannot always demand to be the fairy queen, or soon they have no playmates. Also, because kids enjoy the activity, they do not give up as easily in the face of frustration as they might on, say, a math problem—which helps them develop persistence.

Keeping things friendly requires a fair bit of communication—arguably the most valuable social skill of all. Play that transpires with peers is the most important in this regard. Studies show that children use more sophisticated language when playing with other children than when playing with adults. In pre-

tend play, for instance, "they have to communicate about something that's not physically present, so they have to use complicated language in such a way that they can communicate to their peers what it is that they're trying to say," Pellegrini says. For example, kids can't get away with just asking, "Vanilla or chocolate?" as they hand a friend an imaginary cone. They have to provide contextual clues: "Vanilla or chocolate ice cream: Which one would you like?" Adults, on the other hand, fill in the blanks themselves, making things easier for kids.

If play helps children become socialized, then lack of play should impede social development—and studies suggest that it does. According to a 1997 study of children living in poverty and at high risk of school failure, published by the HighScope Educational Research Foundation in Ypsilanti, Mich., kids who enrolled in play-oriented preschools are more socially adjusted later in life than are kids who attended play-free preschools where they were constantly instructed by teachers. By age 23, more than one third of kids who had attended instruction-oriented preschools had been arrested for a felony as compared with fewer than one tenth of the kids who had been in play-oriented preschools. And as adults, fewer than 7 percent of the play-oriented preschool attendees had ever been suspended from work, but more than a quarter of the directly instructed kids had.

Animal studies lend support to the idea that play deprivation leads to poor social skills. According to a study published in 1999 in *Behavioural Brain Research*, rats that are kept isolated during the two weeks of development when they most frequently play—the fourth and fifth weeks after birth—are much less socially active when they later encounter other rats as compared with rats that are not isolated during the same two-week period. And a study that was published in 2002 in *Developmental Psychobiology* revealed that male rats reared in isolation during their youth fail to display normal avoidance behaviors when introduced to dominant male rats that repeatedly attack them. Could play deprivation specifically cause these behavioral problems—or could social isolation in general have been the culprit?

Another study suggests that play promotes neural development in "higher" brain areas involved in emotional reactions and social learning. Scientists reported in 2003 that play fighting releases brain-derived neurotrophic factor (BDNF)—a protein that stimulates the growth of new neurons—in these regions. The researchers allowed 13 control rats to play freely with companions for three and a half days and kept 14 other rats isolated for the same period. On examining the rats' brains, the researchers found that the cortex, hippo-

Many children (especially boys) like to engage in mock fighting, or rough-and-tumble play. Such roughhousing has been shown to improve creativity, social skills and problem-solving abilities.

PETER MASON *Getty Images*

campus, amygdala and pons of the rats that had played contained much higher levels of BDNF than those of the rats that had not. "I think play is the major mechanism whereby higher regions of the brain get socialized," says Washington State University neuroscientist Jaak Panksepp, who co-authored the study.

STRESS RELIEF

Research suggests that play is also critical for emotional health, possibly because it helps kids work through anxiety and stress. In a 1984 study published in the *Journal of Child Psychology and Psychiatry*, researchers assessed the anxiety levels of 74 three- and four-year-old children on their first day of preschool as indicated by their behavior—whether they pleaded, whined and begged their parents to stay—and how much their palms were sweating. Based on the researchers' observations, they labeled each child as either anxious or not anxious. They then randomly split the 74 kids into four groups. Half of the kids were escorted to rooms full of toys, where they played either alone or with peers for 15 minutes; the other half were told to sit at a small table either alone or with peers and listen to a teacher tell a story for 15 minutes.

Afterward, the kids' levels of distress were assessed again. The anxiety levels of the anxious kids who had played had dropped by more than twice as much as compared with the anxious kids who had listened to the story. (The kids who were not anxious to begin with stayed about the same.) Interestingly, those who played alone calmed down more than the ones who played with peers. The researchers speculate that through imaginative play, which is most easily initiated alone, children build fantasies that help them cope with difficult situations.

Animal studies also support the idea that play helps to alleviate stress—a concept known in neuroscience as social buffering. In a study published in 2008, Gettysburg College neuroscientist Stephen Siviy put rats into a chamber by themselves and exposed them to a collar

all work and no play...

MIKE POWELL *Getty Images*

Although researchers usually emphasize the positive effect of play on the developing brain, they have found that play is important for adults, too. Without play, adults may end up getting burned out from the "hustle-bustle busyness that we all get involved in," says Marc Bekoff, an evolutionary biologist at the University of Colorado Boulder. Adults who do not play may end up unhappy and exhausted without understanding exactly why.

So how can adults get more play into their lives? Stuart Brown, psychiatrist and founder of the National Institute for Play in Carmel Valley, Calif., suggests three ways:

BODY PLAY

Participate in some form of active movement that has no time pressures or expected outcome. (If you are exercising just to burn fat, that is not play!)

OBJECT PLAY

Use your hands to create something you enjoy. (It can be anything; again, there doesn't have to be a specific goal.)

SOCIAL PLAY

Join other people in seemingly purposeless social activities, "from small talk to verbal jousting," Brown suggests.

If you are still not sure what to do, try to remember what you enjoyed doing as a child. "Find your childhood play's 'true north'" and try to translate those memories into activities that fit the current circumstances, Brown says. You might even spark your memory better if you spend a little time around kids, notes Gordon M. Burghardt, an evolutionary biologist at the University of Tennessee.

Ultimately what matters is not *how* you play but *that* you play. And to make sure you do, schedule time in your day for it, Bekoff suggests. "Work will always get done," he says. "In fact, I know that if I don't play, I really don't get more work done." And, Burghardt adds, the happiness and renewed energy you will experience from playing will "more than compensate for the time 'lost.'" —*M.W.M.*

previously worn by a cat, which made them visibly anxious. Later, the chamber was cleaned so it no longer smelled of the cat, the rats were put back in without the cat collar, and the rats immediately became anxious again, probably because they associated the space with the cat. But if Siviy and his colleagues then introduced another rat into the chamber—one that had never been exposed to the cat collar and was not afraid—the two would begin playing by chasing each other, tumbling and pretend fighting. And shortly thereafter, the first rat would relax and become calm, suggesting that play helped the rat to lessen its anxiety.

PLAY TO THE HEAD OF THE CLASS

Relieving stress and building social skills may seem to be obvious benefits of play. But research hints at a third, more counterintuitive area of influence: play actually appears to make kids smarter. In a classic study published in 1973 in *Developmental Psychology*, researchers divided 90 preschool children into three groups. One group was told to play freely with four common objects—among the choices were a pile of paper towels, a screwdriver, a wood board and a pile of paper clips. A second set was asked to imitate an experimenter using the four objects in common ways. The last group was told to sit at a table and draw whatever they wanted, without ever seeing the objects. Each scenario lasted 10 minutes. Immediately afterward, the researchers asked the children to come up with ideas for how one of the objects could be used. The kids who had played with the objects named, on average, three times as many nonstandard, creative uses for the objects than the youths in either of the other two groups did, suggesting that play does foster creative thinking.

Play fighting also improves problem solving. According to a paper published in 1989 by Pellegrini, the more elementary school boys engaged in rough-housing, the better they scored on a test of social problem solving. During the test, researchers presented kids with five pictures of a child trying to get a toy from a peer and five pictures of a child trying to avoid being scolded by his mother. The subjects were then asked to come up with as many possible solutions to each social problem; their score was based on the variety of strategies they mentioned, and children who play-fought regularly tended to score much better.

Through play, animals learn to try new things, and those that do not play simply do not acquire this same behavioral flexibility.

Pellegrini does question, however, how much cause and effect one can glean from these studies. "What does play do? Is it the vanguard of learning something—so does play precede those sorts of skills—or is it merely practice or consolidation of skills that are already developing?" he asks. In 2012 researchers at the University of Virginia analyzed the scientific literature and concluded that play could simply be a sign of healthy development or, alternatively, that it might be one of many activities that makes a difference to the developing brain. But Pellegrini maintains that "either way, at some level, it would be beneficial."

Does lack of play, then, impede the development of problem-solving skills? Perhaps, according to animal studies. In a paper published in 1978 in *Developmental Psychobiology*, experimenters separated young rats by mesh partitions—they could see, smell and hear other rats but could not play with them—for the 20 days during development when they would have most frequently played. The researchers taught these rats, and a group that had been allowed to play without constraints, to pull a rubber ball out of the way to get a food treat. A few days later they switched the setup so the rats would have to push the same ball to get the treat. The isolated rats took much longer to try new ap-

One study found that kids who played with blocks scored higher on language tests than kids who had no blocks. Perhaps the children with blocks simply spent less time on activities such as watching TV—but the end result was good for them in any case.

JUPITERIMAGES

proaches, and thus solve the problem, than did the rats that had played. The authors speculate that through play, animals learn to try new things, and those that do not play simply do not acquire this same behavioral flexibility.

Playing also appears to help with language development, according to a 2007 study in the *Archives of Pediatrics & Adolescent Medicine*. Researchers at the University of Washington gave a box of toy blocks to children from middle- and low-income families aged 18 months to two and a half years. Parents of these kids, as well as parents of a similar group of kids who had no blocks, kept track of how often the children played. After six months, the kids who had played with blocks scored significantly higher on language tests than the others did. But why might play help kids excel?

Animal researchers believe that play serves as a kind of training for the unexpected. "Play is like a kaleidoscope," says evolutionary biologist Marc Bekoff of the University of Colorado Boulder, in that it is random and creative. The bottom line, he posits, is that play encourages flexibility and creativity that may, in the future, be advantageous in unexpected situations or new environments. Some child psychologists, such as Tufts University child development expert David Elkind, agree. Play is "a way in which children learn," Elkind points out, "and in the absence of play, children miss learning experiences."

LET LOOSE

If play is so crucial, what happens to children who are not playing enough? Ultimately no one knows—but many psychologists are worried. Because play is somewhat risky—animals that are not alert and watchful are at risk of being attacked by predators—it probably evolved and persists because it confers survival advantages. "If it wasn't important, it wouldn't have evolved in its elaborate form," Bekoff says.

Indeed, evidence indicates that play is evolutionarily quite ancient. Rats that have had their neocortex removed—a large brain region that is involved in higher-order thinking such as conscious thought and decision making—still engage in normal play, which suggests that play motivation comes from the brain stem, a structure that precedes the evolution of mammals.

Far from engaging in mindless destruction, children who explore everyday objects by playing with them in unusual (albeit sometimes messy) ways are developing their creativity.

CORBIS

Of course, many parents today believe they are acting in their kids' best interests when they swap free play for what they see as valuable learning activities. Some mothers and fathers may also hesitate to let their sons and daughters play outside unattended, and they may fret about the possibility of the scrapes and broken bones that sometimes arise during rambunctious play, says Sergio M. Pellis, a behavioral neuroscientist at the University of Lethbridge in Alberta. Although those parental instincts are natural, protecting youngsters "simply defrays those costs to later, when those same children will have difficulty in dealing with an unpredictable, complex world," Pellis says. A 2015 systematic review reported that risky outdoor play—climbing on high playground structures, for instance, or engaging in rough-and-tumble play—was associated with better physical health among kids, not worse, and that it was also linked to greater creativity and resilience.

Parents should let children be children—not just because it should be fun to be a child but because denying youth's unfettered joys keeps kids from developing into inquisitive, creative creatures, Elkind warns. "Play has to be reframed and seen not as an opposite to work but rather as a complement," he says. "Curiosity, imagination and creativity are like muscles: if you don't use them, you lose them." M

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RAISE GREAT KIDS

WHAT MAKES A GOOD PARENT?

By
Robert Epstein

A scientific analysis ranks the 10 most effective child-rearing practices. Surprisingly, some don't even involve the kids

If you search the book section of Amazon.com for "dieting," you will find more than 76,000 listings. But "parenting" yields a much bigger number: more than *180,000*, including books such as Jane Rankin's *Parenting Experts*, which do nothing but evaluate the often conflicting advice the experts offer. People, it seems, are even more nervous about their parenting than they are about their waistlines.

Why is there such chaos and doubt when it comes to parenting? Why, in fact, do most parents continue to parent pretty much the way their own parents did—or, if they disliked the way they were raised, the exact *opposite* way? Shouldn't we all just find out what the studies say and parent accordingly?

A growing body of research conduct-

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ed over the past 50 years shows fairly clearly that some parenting practices produce better outcomes than others—that is, better relationships between parent and child and happier, healthier, better functioning children. And just as we use medical science cautiously and strategically to make everyday health decisions, we can also make wise use of research to become better parents.

A recent study I conducted with Shannon L. Fox, then a student at the University of California, San Diego, which we presented at a meeting of the American Psychological Association, compared the effectiveness of 10 kinds of parenting practices that have gotten the thumbs-up in various scientific studies. It also showed how parenting experts rate those practices and looked at just how many parents actually use those practices. In other words, we compared three things: what experts advise, what really seems to work and what parents actually do.

Our study confirmed some widely held beliefs about parenting—for example, that showing your kids that you love them is essential—and it also yielded some surprises, especially regarding the importance of a parent's ability to manage stress in his or her own life.

TEN IMPORTANT COMPETENCIES

To figure out which parenting skills were most important, we looked at data from about 2,000 parents who had recently taken an online test of parenting skills I developed (which is accessible at http://MyParentingSkills.com) and who also answered questions about their children. Parents did not know this when they took the test, but the skills were organized into 10 categories, all of which derive from published studies that show that such skills are associated with good outcomes with children. The 10 skill areas measured by the test were also evaluated by 11 parenting experts unknown to Fox and me, and we in turn were unknown to them (in other words, using a double-blind evaluation procedure).

On the test, parents indicated for 100 items how much they agreed with statements such as "I generally encourage my child to make his or her own choices," "I try to involve my child in healthful outdoor activities" and "No matter how busy I am, I try to spend quality time with my child." Test takers clicked their level of agreement on a five-point scale from "agree" to "disagree." Because all the items were derived from published studies, the answers allowed us to compute an overall skill level for each test taker, as well as separate skill levels in each of the 10 competency areas. Agreement with statements that described sound parenting practices (again, according to those studies) yielded higher scores.

The 10 kinds of parenting competencies, which we call "The Parents' Ten," include obvious ones such as managing problem behavior and expressing love and affection, as well as practices that affect children indirectly, such as maintaining a good relationship with one's co-parent and having practical life skills [*see box on opposite page for a complete list*].

In addition to asking test takers basic demographic questions about their age, education, marital status, parenting experience, and so on, we also asked them questions about the outcomes of their parenting, such as "How happy have your children been (on average)?"; "How successful have your children been in school or work settings (on average)?"; and "How good has your relationship been with your children (on average)?" For questions such as these, test takers clicked on a 10-point scale from low to high.

With scores in hand for each parent on all "The Parents' Ten," along with their general assessments regarding the outcomes of their parenting, we could now use a statistical technique called regression analysis to determine which competencies best predict good parenting outcomes. For an outcome such as the child's happiness, this kind of analysis allows us to say which parenting skills are associated with the most happiness in children.

LOVE, AUTONOMY AND SURPRISES

Our most important finding confirmed what most parents already believe, namely, that the best thing we can do for our children is to give them lots of love and affection. Our experts agreed, and our data showed that this skill set is an excellent predictor of good outcomes with children: of the quality of the relationship we have with our children, of their happiness, and even of their health. What's more, parents are better at this skill than they are at any of the others. We also confirmed what many other studies have shown: that encouraging children to become independent and autonomous helps them to function at a high level.

But our study also yielded a number of surprises. The most surprising finding was that two of the best predictors of good outcomes with children are in fact *indirect:* maintaining a good relationship with the other parent and managing your own stress level. In other words, your children benefit not just from how you treat *them* but also from how you treat your partner and yourself.

Getting along with the other parent is necessary because children inherently want their parents to get along. Many years ago, when my first marriage was failing, my six-year-old son once led me by the hand into the kitchen where his mom was standing and tried to tape our hands together. It was a desperate act that conveyed the message: "Please love each other. Please get along." Children do not like conflict, especially when it involves the two people in the world they

FAST FACTS

ESSENTIAL PARENTING SKILLS

1. Decades of research reveal 10 essential parenting skill sets. A study of 2,000 parents determined which skills are most important to bringing up healthy, happy and successful kids.
2. Giving love and affection tops the list. Then comes a surprise: managing stress and having a good relationship with the other parent are more helpful than some child-focused behaviors.
3. All types of people are equally competent at child-rearing—and anyone can learn how to be a better parent with a little effort.

The Parents' Ten

Here are 10 competencies that predict good parenting outcomes, listed roughly in order from most to least important. The skills—all derived from published studies—were ranked based on how well they predict a strong parent-child bond and children's happiness, health and success. *—R.E.*

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1. **Love and affection**
   You support and accept the child, are physically affectionate and spend quality one-on-one time together.
2. **Stress management**
   You take steps to reduce stress for yourself and your child, practice relaxation techniques and promote positive interpretations of events.
3. **Relationship skills**
   You maintain a healthy relationship with your spouse, significant other or co-parent and model effective relationship skills with other people.
4. **Autonomy and independence**
   You treat your child with respect and encourage him or her to become self-sufficient and self-reliant.
5. **Education and learning**
   You promote and model learning and provide educational opportunities for your child.
6. **Life skills**
   You provide for your child, have a steady income and plan for the future.
7. **Behavior management**
   You make extensive use of positive reinforcement and punish only when other methods of managing behavior have failed.
8. **Health**
   You model a healthy lifestyle and good habits, such as regular exercise and proper nutrition, for your child.
9. **Religion**
   You support spiritual or religious development and participate in spiritual or religious activities.
10. **Safety**
    You take precautions to protect your child and maintain awareness of the child's activities and friends.

love most. Even in co-parenting situations where parents live apart, it is crucial to adhere to practices that do not hurt children: to resolve conflicts out of sight of the children, to apologize to one another and forgive each other (both can be done in front of the kids), to speak kindly about the other parent, and so on.

Stress management is also important for good parenting, just as it is vital in all aspects of life. In our study, parents' ability to manage stress was a good predictor of the quality of their relationship with their kids and of how happy their children were. Perhaps more telling, people who rated themselves as great parents scored more highly on stress management than on any of the other nine parenting competencies. There is, possibly, a simple lesson here: parents who lose their temper around their kids know it is bad parenting. Keeping calm is probably step one in good parenting. Fortunately, stress-management practices such as meditation, imagery techniques and breathing exercises can be learned, no matter what one's natural tendencies. People can also learn better organizational skills and even ways of managing stressful thinking.

Keeping children safe—a matter of almost obsessive concern among American parents these days—seems to have both positive and negative outcomes. On the bright side, in our study safety skills did contribute to good health outcomes. But being overly concerned with safety appears to produce poorer relationships with children and appears to make children less happy. A study by Barbara Morrongiello and her colleagues at the University of Guelph in Ontario shows how complex the safety issue can be. In their study, young people between the ages of seven and 12 said that even though they were generally conforming to the safety rules of their parents, they planned to behave like their parents when they grew up, even where their parents were, by their own standards, behaving unsafely. Had they detected their parents' hypocrisy?

Another surprise involves the use of behavior-management techniques. Although my own training in psychology (under the pioneering behavioral psychologist B. F. Skinner) suggests that sound behavior management—providing lots of reinforcement for good behavior,

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for example—is essential for good parenting, our study casts doubt on this idea. Behavior management ranked low across the board: it was a poor predictor of good outcomes with children; parents scored relatively poorly in this skill area; and our experts ranked it ninth in our list of 10 competencies.

In general, we found that parents are far better at educating their children and keeping them safe than they are at managing stress or maintaining a good relationship with the other parent, even though the latter practices appear to have more influence on children. Getting along with one's co-parent is the third most important practice, but it ranked eighth on the parents' list of actual abilities. Even more discouraging, stress management (number two in importance) ranked 10th.

WHO MAKE GOOD PARENTS?

Setting aside "The Parents' Ten" for the moment, our study also shed some interesting light on what characteristics a good parent has.

A general parenting ability appears to exist—something like the "g" factor that exists for intelligence (also known as general intelligence). The g factor for parenting emerged very strongly in our study using a statistical technique called factor analysis, which organizes large amounts of test data by clustering test items into a small number of highly predictive variables. Some people just seem to have a knack for parenting, which cannot be easily described in terms of specific skills.

We also found that a number of characteristics that people often associate with good parenting are probably not very significant. For example, women appear to be only a hair better than men at parenting these days—a huge change in our culture. Women scored 79.7 percent on our test, compared with 78.5 percent for men—a difference that was only marginally significant. Parents who were older or who had more children also did not produce significantly better parenting outcomes in our study. Parents seem to perform just as well whether or not they have ever been married, and divorced parents appear to be every bit as competent as those who are still married, although their children are somewhat less happy than the children of parents who were never divorced.

Neither race nor ethnicity seems to contribute much to parenting competence, and gays and straights are just about equal in parenting ability. In fact, gays actually outscored straights by about 1 percentage point in our test.

One characteristic that does seem to make a difference is education: generally speaking, the more the education, the better the parenting. This might be because better educated people also work harder to improve their parenting skills through parent education programs (confirmed by our data). It is also possible that good parents—those with a high parenting g—are also generally competent people who are better educated. In other words, the g for parenting might be the same as the g for intelligence, a matter to be explored in future research.

The bottom line on such findings is that if you really want to know about an individual's competence as a parent, you should measure that competence directly rather than default to commonly held stereotypes. In the U.S., after all, women did not get the vote until 1920 because of faulty assumptions about female limitations. I believe this is one of the main lessons of our study: there is simply no substitute for the direct measure of competence.

Perhaps the best news is that parents are trainable. Our data confirm that parents who have taken parenting classes produce better outcomes with their children than parents who lack such training and that more training leads to better outcomes. Training programs, such as the evidence-based Parenting Wisely program developed by Donald A. Gordon, of Ohio University, can indeed improve parenting practices. Programs are available in major cities around the country, sometimes sponsored by local therapists or state or county agencies. The National Effective Parenting Initiative, which I have been associated with since its inception in 2007, is working to make quality parent training more widely available (see http://EffectiveParentingUSA.org for additional information).

WHERE EXPERTS FAIL

Although parenting experts do indeed offer conflicting advice at times (perhaps

Ewww … gross! Maintaining a healthy relationship with your co-parent (spouse or otherwise) is one of the most important child-rearing practices. It is good for kids to see respect, forgiveness and, yes, even love and affection.

TANYA LITTLE *Getty Images*

Parents who focus too much on keeping their children safe may see their efforts backfire, winding up with unhappy kids or a poor parent-child relationship. Kids fare better when parents encourage autonomy.

GETTY IMAGES

because they don't keep up with the studies!), our experts generally did a good job of identifying competencies that predict positive outcomes with children. There were two notable exceptions: First, they ranked stress management eighth in our list of 10 competencies, even though it appears to be one of the most important competencies. Second, our experts seemed to be biased against the religion and spirituality competency. They ranked it rock bottom in the list of 10, and several even volunteered negative comments about this competency area, even though studies suggest that religious or spiritual training is good for children.

Historically, clinicians and behavioral scientists have shied away from religious issues, at least in their professional lives; that could explain the discomfort our experts expressed about religious or spiritual training for children. Why they were so far off on stress management is truly a mystery, however, given psychology's long interest in both the study and treatment of stress. I can only speculate that stress management is not widely taught in graduate programs in psychology-related fields as an essential component of good parenting. It should be.

BRINGING IT HOME

Tempering one's parenting with relevant scientific knowledge can truly have great benefits for one's family. It can reduce or eliminate conflict with one's children, for one thing, which in turn can improve a marriage or co-parenting relationship. It can also help produce happier, more capable children.

I have seen how this works in my own parenting. I am a much better parent with my younger children (who range in age from nine to 17) than I was with my older two (now 34 and 36). The more I have learned about parenting over the years, the more loving and skillful I have become, with obvious benefits. These days I really do hug my children and tell them I love them several times a day, every day, without exception. When love is never in question, children are much more understanding and tolerant when a parent needs to set limits, which I do regularly. I have also learned to stay calm—to improve the way I react to things. When I am calm, my children are, too, and we avoid that deadly cycle of emotional escalation that can ruin relationships.

Most important, I am much more a facilitator now than a controller. While building my own competence as a parent, I have also put more effort into recognizing and strengthening the competence of my children, helping them to become strong and independent in many ways. My 17-year-old son is now a calm, helpful role model to his siblings, and by the time she was 10, even before I had gotten out of bed, my daughter had often made scrambled eggs for all of us—and cleaned up, too. M

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- **The Process of Parenting.** Ninth edition. Jane B. Brooks. McGraw-Hill Education, 2012.
- To take the author's parenting tests, visit **http://MyParentingSkills.com** and **http://TeenParentingSkills.com**

OH, BEHAVE!

RAISE GREAT KIDS

An interactive parent-training program can stamp out behavior problems in kids—and abuse from parents

By Ingrid Wickelgren

On a summer day in 2013, psychologist Steven Kurtz is preparing one of his clients, Maria, for a therapy session. A calm, cheerful woman with long, dark hair, Maria has been in training at the Child Mind Institute in New York City with her six-year-old son, Ryan (not his real name), for months to ready him for this day. Her goal seems simple: to coax Ryan to obey a simple command. But Ryan does not take direction well.

Maria and Ryan are undertaking a brand of parent training called Parent-Child Interaction Therapy (PCIT) designed to correct oppositional behavior in children. Until now, Maria has let Ryan pick their activities. Today, for the first time, Maria will choose something to do.

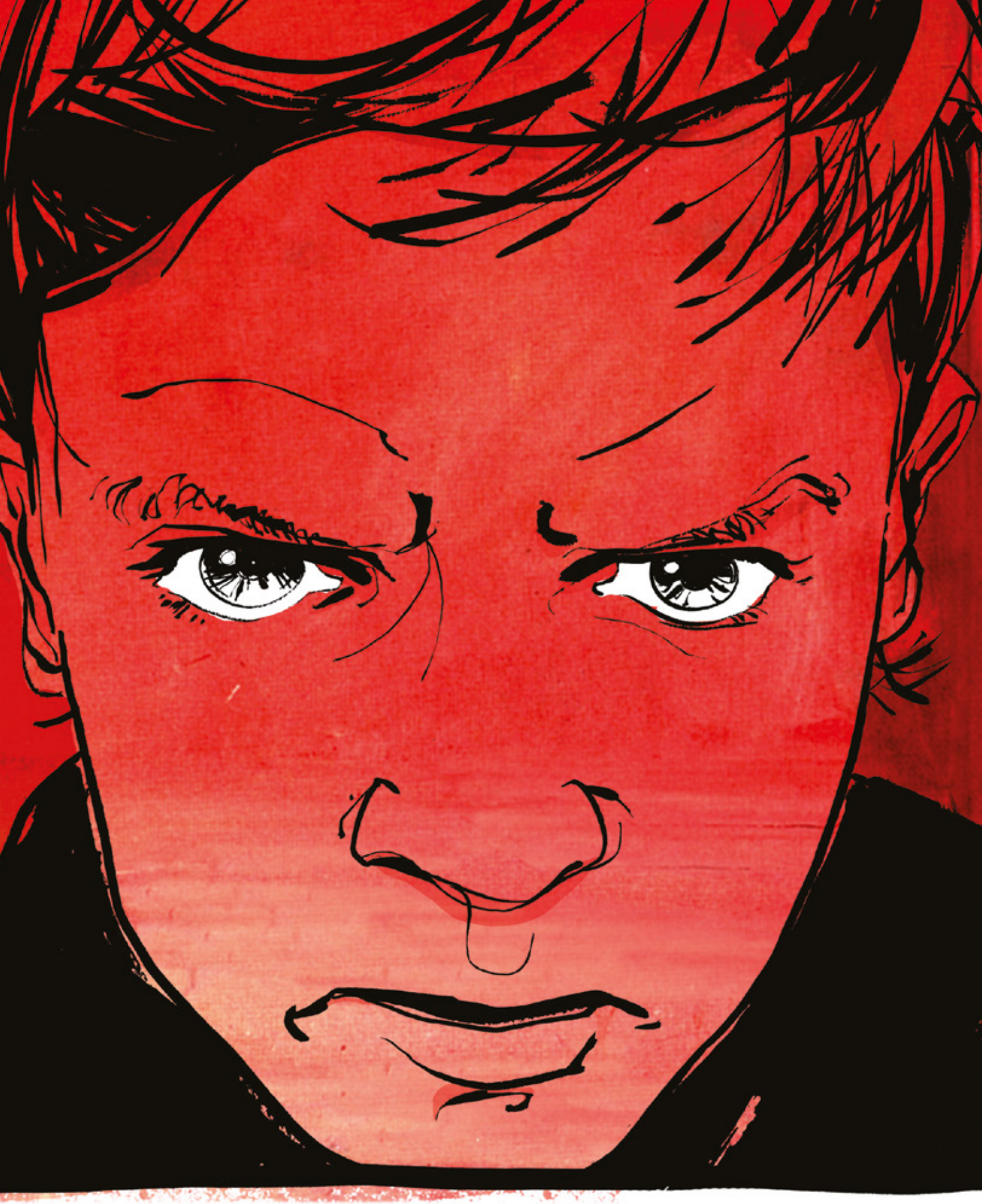
One command at a time, Kurtz tells Maria. She practices: "Can you give me the blue piece?" The psychologist corrects her: "Give me the blue piece." Commands must be direct, to avoid any implication of a choice. Praise immediately if he obeys, Kurtz advises. When he does not, say: "If you don't hand me the blue piece, you have to sit in the time-out chair." If he gets off the chair, Mom's line is: "You got off the chair before I said you could. If you get off the chair again, you will have to go to the time-out room."

"Like the Lord's Prayer, the words are always the same." Kurtz explains. "Spoken with the same intonation."

Kurtz removes the bins for storing toys now in the room; they are more likely to be used as weapons than for cleanup, he reasons. Another issue is Ryan. He is at a computer downstairs and feels like staying there. When Maria drags the thin, dark-haired boy into the room, he is scowling. "This is boring!" he shouts.

Kurtz explains the new rules to Ryan. "Until now,

Illustrations By PJ Loughran



you've been choosing the activities." Today, Kurtz says, "Mom is going to take turns with you."

"Hey—I have this car. I have this car!" the boy interrupts. He is holding one of the toy cars in the room. Kurtz continues: "When Mom chooses the activity, it's very important that you follow her directions. If you don't, she is going to tell you to go in this chair. If you stay in this chair, you get to go back and play with her again. If you don't, you have to go in this room." He gestures toward the door of a narrow enclosure in one corner of the room. "No, I will stay in here!" Ryan yells.

Kurtz exits and sets up shop in a small observation room behind a wall of one-way glass. Kurtz can watch the pair, but they cannot see him. Maria will listen to his directions through an earbud she is wearing.

Maria tells Ryan that their special time is beginning. "Would you like to pick an activity?" she asks. Ryan is throwing toys around the room. "Hold off on all instructions until later," Kurtz advises. "What is he doing?" The therapy calls for narrating a child's actions, to show interest and help focus a child's attention on a task. "Right now he's playing with the cars," Maria says.

Cars are flying around the room. Bang! Crash! Bang! Maria does not scold, shout or even look at Ryan. She stares straight ahead. "Look for that split second he does something you like," Kurtz advises. "When he stops throwing ... for a second ..."

Most young children willfully disobey or throw tantrums from time to time. Yet when every routine task—fastening a seatbelt, holding hands at the corner, getting dressed—ignites a confrontation, parents often seek help. Designed for kids who are two to seven years old, PCIT changes the way parents respond to their children. It strengthens the bond between parent and child while providing consistent rules and incentives for cooperation.

Rather than treating a disorder, PCIT is aimed more broadly at disruptive behavior, which can range from talking back to severe aggression. The most common mental health concern for young children, disruptive behavior is a feature of several different diagnoses, including oppositional defiant disorder (ODD)—extreme disobedience and hostility toward authority figures—and conduct disorder, in which kids flaunt rules, fight, lie, steal and engage in other alarmingly bad behavior.

Ryan has attention-deficit/hyperactivity disorder (ADHD), which often spurs conduct problems. He is not so much driven to defiance as he is inexorably drawn to whatever is most alluring at the moment—a television show, hot chocolate, a playground, even sleep. His need to pursue his current activity causes him to refuse conflicting requests or demands. Every morning Maria had forcibly pulled Ryan out of bed and dressed him. When Ryan's grandmother had taken care of him after school and turned off the TV, Ryan angrily threw all the available books and toys onto the floor.

About 150 research articles, including eight randomized trials, have demonstrated that PCIT is highly effective in ameliorating such reactions, and the gains are lasting. The stakes go beyond family dynamics. Little kids with significant behavior problems are at high risk of serious antisocial behavior later on. "Previous research is very clear: if early child behavior problems are not corrected, they are likely to escalate to behaviors that are more destructive and intractable," says Jennifer Wyatt Kaminski, a developmental psychologist at the National Center on Birth Defects and Developmental Disabilities. "Preventing risky and violent behavior in adolescents is an important public health issue."

Because of its scientific backing, PCIT is gaining international recognition and making rapid headway into clinics in about 20 percent of the country—principally, Delaware, California, the Carolinas, Pennsylvania, Oklahoma, Iowa, Minnesota, Oregon and Washington—where large-scale training programs are in effect. The therapy is poised to become more widely disseminated now that PCIT International, an organization established in 2009, has rolled out its protocol for certifying therapists. More than 200 therapists are now certified to conduct PCIT.

Recent adaptations have retrofitted the approach to suit older children, and—taking advantage of its emphasis on parenting skills—to prevent relapse in abusive parents. PCIT offers useful tactics, too, for controlling more moderate forms of troublesome behavior in children. "It is a way to change your vocabulary and speak to your kids in a positive manner," says Joshua Masse, a clinical psychologist at the University of Massachusetts at Dartmouth. Kurtz, who now runs his own private practice, adds, "This is the manual that parents should be given."

"YOUR IMAGINATION FLIES LIKE YOUR ROBOT"

PCIT got its start in the early 1970s, when Sheila M. Eyberg was a clinical psychology intern at the Oregon Health Sciences University. She treated behavior problems with play therapy, in which a therapist coaches a child to describe his or her emotions during playtime, as a route toward self-acceptance. Eyberg noticed that her charges "seemed to calm down, 'self-correct,' and try to please

FAST FACTS

FAMILY MATTERS

1. A brand of parent training called Parent-Child Interaction Therapy (PCIT) can correct oppositional behavior in children two to seven years old.
2. Little kids with significant behavior problems are at high risk of serious antisocial behavior later on.
3. Because of its scientific backing, PCIT is gaining international recognition and making headway in states where large-scale training programs are in effect.
4. The approach has stopped parents in the child welfare system from continuing to abuse their children.

me," she wrote in *PCIT Pages: The Parent-Child Interaction Therapy Newsletter* in 2004. But, she penned, "their parents were not reporting similar experiences at home. Nor were they reporting changes in their children's behaviors." Instead of bonding with their parents, the kids were connecting with Eyberg.

The late psychologist Constance Hanf, also then at O.H.S.U., was piloting an approach that addressed these concerns. She was training mothers to act as therapists for their children, who had developmental disabilities. A key target of Hanf's program was the parent-child bond. According to attachment theory, that bond provides a secure base from which a child can explore the world and helps that child control his or her emotions. In Hanf's therapy, parents built that connection while playing a game of the child's choosing. As one of Hanf's students, Eyberg constructed PCIT around her teacher's scaffold.

Last summer Laura (not her real name), a fun-loving young mother, gave a textbook demonstration of this element of PCIT during one of her therapy sessions. Her son, whom I will call Gabriel, a small six-year-old with light brown, curly hair, had just created a robot out of magnets.

"Oh, you choose to play with the magnets!" Laura says. "Beautiful robot. I love it."

"Now it's a castle," Gabriel says of his creation. Gabriel has ODD.

"It's so smart—you converted a robot into a castle," his mother says.

Gabriel sticks out his tongue. "You're sticking out your tongue," Laura narrates.

"People hate him so he started to transform," Gabriel says of his robot.

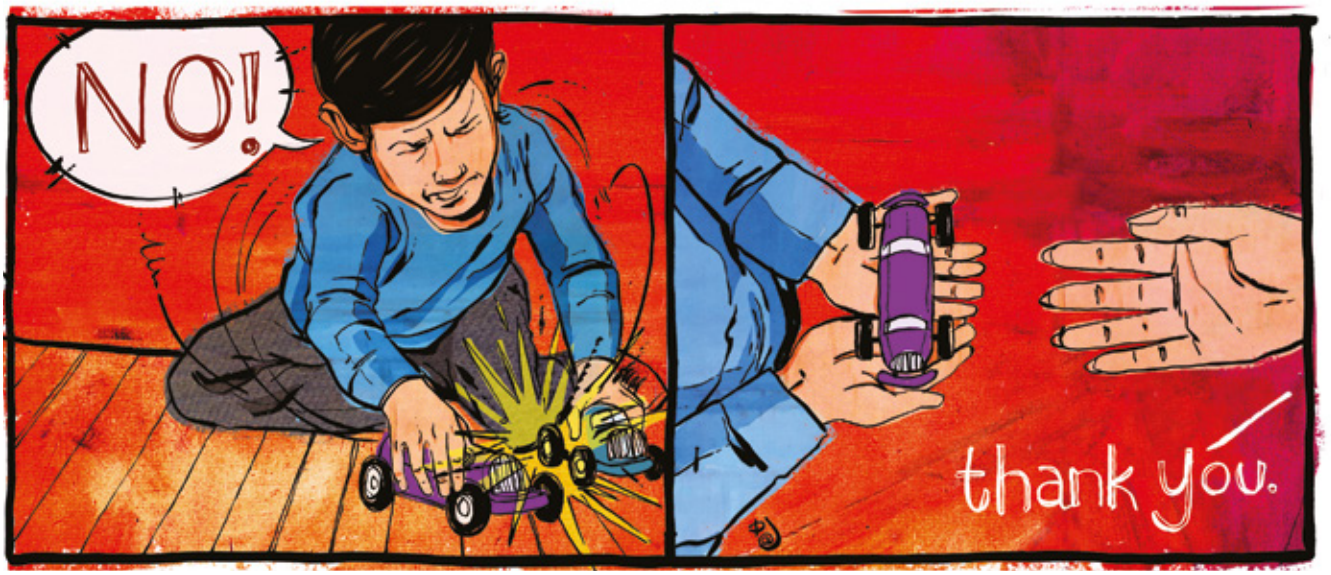
"That's very smart," his mother compliments. "Thank you for telling me the whole story." Gabriel starts speaking in a funny, robotic voice. Laura copies him.

"Your imagination flies like your robot," Laura says. "You can come up with different designs like this. It's amazing to me."

Laura describes and imitates Gabriel's actions, repeats what he says—all of which let the child lead—and acts happy and relaxed. Laura's behavioral descriptions also show she is interested, demonstrate proper speech and help Gabriel stay focused on the task. Laura frequently praises the boy, telling him exactly what she likes about what he is doing. In addition, parents are told to ignore minor misbehavior, so that the child learns that only behaving appropriately earns him attention. Laura has met the criteria for mastery: in five minutes, she issues five behavioral descriptions, five reflections, 15 praises, and fewer than three commands, questions and criticisms.

The second phase of PCIT, which Maria and Ryan were just starting, is directed at limit setting and discipline. It is also based on Hanf's therapy, which included a component geared toward controlling behavior. Parents guide a child with clear instructions and consistent consequences, such as praise for compliance and time-out for disobedience. Parents graduate from this phase when three quarters of their commands are direct and the child complies with all of them.

Laura is close. Gabriel complies with



To reduce disruptive behavior, parents are advised to ignore minor acts of defiance. But Mom or Dad should praise the child as soon as he or she does something good.

THE AUTHOR

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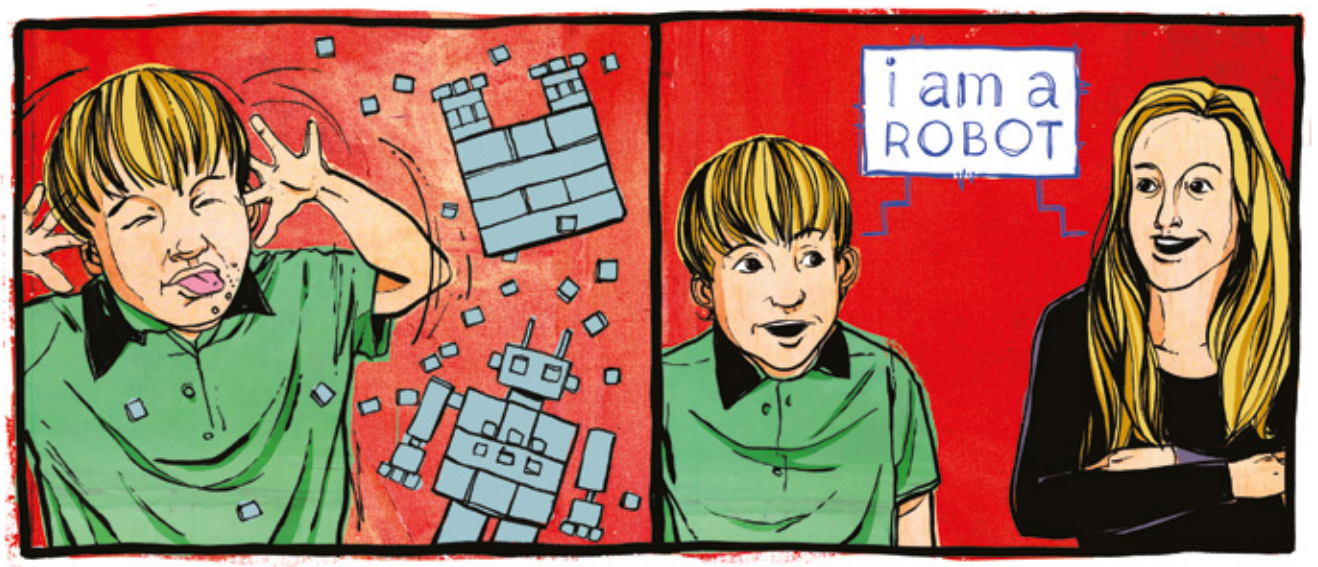
some but not all of her requests. When Laura says she wants to do a puzzle, Gabriel protests: "I am tired of listening! I don't want to do this. Can we go out?" Gabriel does not work on the puzzle for long, but he does eventually agree to sit next to Laura and put the pieces away—and he never needs to sit in the time-out chair, although Laura threatens to put him there.

Gabriel and Laura have already come a long way. Earlier in the year Gabriel had been very unhappy and angry. He acted aggressively toward Laura and refused to obey her. "Get ready for bed or get ready for school ... to get him to do anything was very, very hard," Laura recalls. Now Gabriel complies with her requests much more often. "When I ask him to turn off the iPad, he hands it to me," Laura says. "He knows that if he doesn't, there's a consequence."

In one landmark test of the therapy, published in 1998, Eyberg, now at the University of Florida, and her colleagues gave PCIT to 22 families of three- to six-year-old children with ODD and assigned 27 others to a waiting list. The parents who received treatment interacted with their children more positively, praising them more and criticizing them less, than those on the waiting list. The children of the parents who participated in PCIT, in turn, were more likely to do what was asked of them. These parents noted large improvements at home as well, rating their child's behavior within the normal range, on average, by the end of treatment. Many of these kids no longer qualified for a diagnosis of ODD. A 2003 study revealed that the treated children became even easier to handle in the following three to six years, perhaps because children and parents reinforce one another's good behavior over time.



When a parent repeats what her child says, she lets the child lead, encourages conversation and shows she is engaged. Such mimicry improves the parent-child relationship—and, ultimately, the child's behavior.

In a 2007 meta-analysis (statistical review) of 13 studies of PCIT, psychologists Rae Thomas and Melanie J. Zimmer-Gembeck, both then at Griffith University in Australia, confirmed that the therapy is linked to significantly improved parenting and reduced negative behavior in kids. It boosts warmth from parents, decreases their hostility and reduces their stress. It also diminishes aggression and oppositional behavior among children.

The success of PCIT is thought to stem, in part, from its emphasis on rehearsal of a particularly relevant set of skills. In a meta-analysis of 77 investigations of parent-training programs published in 2008, Kaminski and her colleagues found that requiring parents to practice the appropriate actions with their children during the training sessions seemed to be critical to correcting parent behavior. Kaminski's team also noted that parent proficiency tended to improve whenever moms and dads were taught to talk to their kids about emotions and to effectively listen to them. In addition, the researchers identified the two essential elements to boosting children's behavior ratings: instructing parents to interact positively with their children—expressing enthusiasm and following the child's lead—and to respond consistently to a child's actions.

CHILD PROTECTION

Sometimes the child is not the problem; the parent is. Parenting education and training has been a staple in child welfare for decades. Typically parents discuss their experiences and strategies in groups, but such conversations often fail to change the family dynamic, and parental neglect or abuse persists.

In the early 2000s Mark Chaffin, a child abuse researcher at the University of Oklahoma Health Sciences Center, wanted to test PCIT with such parents on the grounds that teaching skills might

be more effective than discussing concepts. The state child welfare system sent him 110 adults who had been reported multiple times for physical abuse of their children. The parents received 12 to 14 one-hour sessions at the university's large PCIT center. In addition, Chaffin required these mothers and fathers to participate in a motivational exercise. "If your five-year-old is driving you crazy, you are fairly motivated," Chaffin explains. "But we were concerned that people coming from child welfare would not be happy to be sent to a program." In Chaffin's program, parents were asked to consider their parenting goals and whether their actions aligned with those goals.

The combination approach worked. More than two years later only 19 percent of the parents who had received both PCIT and the motivational interview had been reported again for abuse—compared with 49 percent of those who had been assigned to a standard parenting group, according to a 2004 study by Chaffin and his colleagues. "We got large effect sizes in reduction of child welfare recidivism," something that is hard to budge, Chaffin says.

In a follow-up trial published in 2011, Chaffin's team extended these results to more severe cases of abuse and neglect and a more realistic therapeutic setting: a small inner-city agency under contract with the state's child welfare system. Among 192 parents who had averaged six prior referrals to child welfare, a motivational interview along with PCIT led to a recidivism rate of around 17 percent two and a half years later, compared with about 65 percent for those who received standard group therapy along with a motivational interview. "Even if you are motivated, typical group therapy doesn't give you a lot of benefit," Chaffin concludes.

The children involved in Chaffin's studies ranged from four to 12 years old, so he and his colleagues adapted the treatment to older kids. Time-outs were replaced with logical consequences—such as taking away objects that a child is actively misusing—and loss of privileges. And praise was less demonstrative. Instead of exclaiming, "What a nice tower!" to a child playing Legos, a father might challenge his 11-year-old son to a tower-building race. "Oh, you're killing me!" the dad might praise. In a 2012 case study, Eyberg and her colleagues also found that PCIT greatly improved the newly aggressive and oppositional behavior of an 11-year-old who had suffered a traumatic brain injury from a gunshot wound.

"PLEASE HAND ME THE PINK DOUGHNUT"

PCIT holds useful lessons for more ordinary circumstances as well: ignore bad behavior, praise good; tell a child what to do rather than what *not* to do; phrase commands as such, not as questions or suggestions. Indeed, Eyberg and her colleagues found that two abbreviated versions of the technique significantly improved the behavior of 30 three- to six-year-olds whom their mothers had characterized as having moderate behavior problems. Both a four-session group intervention and written materials describing how to practice PCIT garnered similar benefits, suggesting that hands-on coaching may not be necessary in milder cases.

Back at the Child Mind Institute, Ryan has calmed down but balks at the suggestion that he play his mother's game. Soon he is sent to the time-out chair, but he will not sit there voluntarily and gets up repeatedly. Then, before he can be moved to the time-out room, he kicks his mother and pushes *her* into the room, locking her inside, and then knocks over all the big metal chairs. Kurtz intervenes.

For more than an hour, Ryan goes from the time-out room to the time-out chair and back again, crying and protesting all the while. "I'll kill you! I'll kill you! You're nuts!" he shouts. Maria remains calm. She smiles and laughs to help ease the tension.

Finally, Ryan elects to stay in the chair, so Maria attempts a command. She tells Ryan to come sit next to her. "To do what?" he challenges. He is sent back to the chair. Yet again he stays there, whimpering. Twenty minutes later, in response to a period of relative silence, Maria says. "You're sitting quietly. Are you ready to come and sit with me?" "Yes." He walks over to her, sobbing softly.

"Okay. Please hand me the pink doughnut." He finds the pink doughnut from a smattering of plastic toys spread out on the table—and hands it to her.

"Thank you for doing what I told you." She pets his face and smiles. He is still teary.

"Now please hand me the banana." He does.

"Yay! Good listening." She kisses him. Ryan brings his mom one more item, a plastic potato chip, before Kurtz ends the session.

That afternoon Ryan passed another milestone. When Kurtz enters the room, Maria flashes a wide smile. She gives Kurtz a thumbs-up, and the two exchange a high five. Ryan does not feel like celebrating, however. "I had a very hard day," he sighs. **M**

MORE TO EXPLORE

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HELP FOR THE CHILD WITH AUTISM

RAISE GREAT KIDS

By
Nicholas Lange and Christopher J. McDougle

Photographs by
Timothy Archibald

The disorder remains a medical mystery with no cure in sight, but some existing therapies produce lasting benefits, and more are on the horizon

Jayden, playfully upended by his mother, Adrianna Hannon, received a diagnosis of autism at 22 months.

When Adrianna and Jermaine Hannon's second child, Jayden, was 14 months old, the California couple began to worry that something was wrong. The child became preoccupied with toy cars, turning them over and rolling their wheels ceaselessly at an age when most other toddlers flit from one activity to another. Jayden would also line up cars, magazines or blocks on the floor or a table in as straight a line as he could make, never stacking objects as other kids would.

At 16 months, Jayden began to stop blurting the short phrases he had been using for four or five months—"Up, Mom," "Picky-up" and "Abby," his big sister's name—and he rarely looked toward family members when they called. One day around that same age, a large pot dropped by accident near to where Jayden was sitting, but the toddler did not respond at all. The pediatrician told Adrianna not to worry about Jayden's behavior, because child development tends to occur in bursts, especially in boys, and speech often develops later than in girls. At the pediatrician's request, Adrianna and Jermaine took their child to an audiologist to test his hearing, which turned out to be normal.

Jayden took another turn for the worse at 18 months when a high fever of 104 required a visit to the emergency room. A complete medical workup failed to locate the source of the fever, and the child returned home with his parents. The temperature eventually subsided, but Jayden never spoke another word. Neither did he respond when his name was called, and he made eye contact only with his mother.

This alarming series of events in Jayden's life still had not tapered off by 22 months. If he wanted something, he would grab Adrianna's or Jermaine's hand and bring them to the object he desired. He continued to be captivated by toy car wheels, rolling them without pause. He also was enthralled with a Mickey Mouse video on his iPad, which he would play over and over until asked to stop. Jayden loved, too, a program featuring the chugging Thomas the Tank Engine, with its crashing sound effects. His parents eventually decided to bring Jayden to a nearby early intervention clinic for children suspected of having autism, or, in clinical terminology, autism spectrum disorder—a condition marked, to varying degrees, by persistent deficits in communicating and interacting with others and a propensity to engage in repetitive behaviors, such as rocking or repeating sounds over and over.

Based on the careful observation of Jayden over the course of a few hours and on the wealth of details furnished by his parents, a psychologist at the clinic gave Adrianna and Jermaine the devastating news that their child did, indeed, have autism. Both parents initially wondered if they could have done something to cause the disorder. And, despite their suspicions, Adrianna recalls, Jermaine, an engineer, took a while to "get his head around" the clinic's confirmation of their fears. Having taught special education classes for 12 years, Adrianna took the diagnosis more in stride. She kept going by repeating to herself silently: "I can't quit," adding in another inspirational motto: "If I can't give him my all, then what can I expect anyone else to give him?"

Adrianna and Jermaine's experiences with Jayden resemble those of the thousands of parents whose children receive a diagnosis of autism spectrum disorder every year. As in Jayden's case, the condition remains a vexing enigma that taxes a physician's diagnostic powers. In the 70 years since psychiatrist Leo Kanner first coined the term "early infantile autism," scientists have yet to find any objective measurement—whether a molecule, a gene, electrical activity in a brain circuit or a consistent difference in brain size—to pinpoint how it originates.

Researchers are desperately trying to identify such biological clues in the hope that the information will facilitate diagnosis and the development of better treatments. To date, some drugs have shown that they can manage the irritability, mood swings and tantrums that afflict the child with autism. But nothing approved by the Food and Drug Administration deals with the basic symptoms: the language, social problems and repetitive gesturing.

The need is pressing. Estimates by the Centers for Disease Control and Prevention of the prevalence rate of autism (the percentage of people with autism at a particular date) have increased from one in 88 to one in 68 between 2012 and 2014, a 30 percent increase, and the rate continues to move upward. Some of the rise stems from increased screening; the American Academy of Pediatrics recommends examining all children at 18 and 24 months of age for the telltale signs. The trend also results from a broadening of the complex diagnostic criteria for autism spectrum disorder. But even if those changes had not occurred, the numbers of families needing help would be large.

A counterweight to this seemingly bleak outlook lies in encouraging recent developments. In the past few years medical professionals have begun to spread the important message that a few nonpharmaceutical treatments can profoundly help children like Jayden. Begun early, therapies that ground the child with autism in appropriate forms of social behavior—such as looking at a mother's face as she speaks—may mean the difference between years in a special school or institution versus a normal track for the elementary and secondary years and the eventual hope of an adulthood with a job and family. In coming years, what is more, behavioral therapies may be supplemented by new technologies that will

FAST FACTS

HELP FOR AUTISM

1. A deep-seated inability to interact with parents, siblings and other children can sometimes lead to a toddler's receiving a diagnosis of autism at about two years of age.
2. Help may come from early delivery of therapies that improve social communication. Better skills can lay the groundwork for entering regular schools and pursuing relationships with friends and family.
3. Improved understanding of the biology of autism may permit development of new diagnostic techniques and a range of drugs to complement behavioral therapies aimed at enhancing social communication.

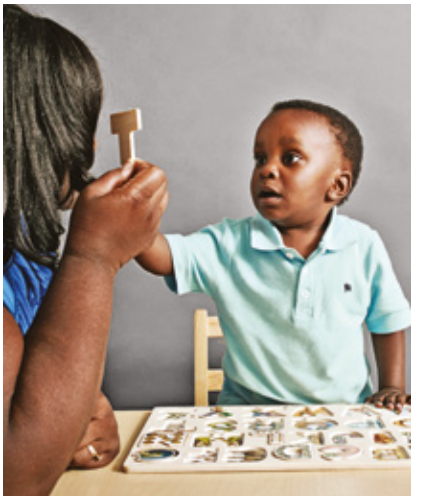
provide a definitive diagnosis before children reach their second birthday and by drugs that may correct biochemical imbalances underlying the disorder.

EARLY INTERVENTIONS BRING HOPE

Waiting another decade for approval of a new drug is an agonizing prospect for the parents of a recently diagnosed child. Initial despair, however, can be tempered by the knowledge that a few good treatment options already exist. The latest research has shown that the brain of a toddler with autism can learn and change in response to behavioral therapies that enhance the plasticity of the young child's brain (brain changes resulting from new inner and outer influences). This flexibility opens new possibilities for intensive one-on-one therapy with trained professionals and parents to alleviate the difficulties with speech and social interactions that are a hallmark of the disorder.

In recent years, nearly half a dozen early-intervention methods have come onto the scene; they are derived from developmental psychology and applied behavior analysis (a technique for improving cognitive, language and social skills). Early-intervention therapists try to deal with the difficulty a child with autism has in heeding social cues—facial expressions, gestures and spoken words. Such treatments draw the attention of children to faces and voices. Healthy youngsters react more to a face than to a block, yet the pattern reverses for the child with autism, who typically responds more to an object than to a parent's gaze.

We are most familiar with the early-intervention therapy called ESDM (Early Start Denver Model), and so we will focus here on that approach. In this method, the therapist tries to encourage the child to focus attention. The professional will present a toy, perhaps name the toy in an inviting way and, when the child looks, will share it and start to play. The therapist tries to keep a child engaged in rounds of play intended to cultivate a liking for social activities, all the while teaching social and communication skills. With funding from the National Institutes of Health,



Mother and child play at the University of California, Davis, where Jayden went at age three for treatment to improve his communication skills.

Geraldine Dawson of Duke University and Sally J. Rogers of the University of California, Davis, have evaluated the technique and reported strong evidence of its effectiveness for autism.

After two years of intensive ESDM training beginning anywhere from 18 to 30 months of age, children paid more attention to faces than did youngsters with autism who were enrolled in intervention programs commonly available in their communities. The children who received ESDM scored higher on cognitive tests: their developmental quotient (an IQ test for very young children) rose in the study by 10.6 points more on average than did that of children in the other treatment programs. The severity of social deficits and repetitive behaviors diminished, although some symptoms not directly related to autism lingered.

Imaging shows that the brain undergoes desirable changes as well. Brain areas activated when a child looks at faces lit up more in children with autism who received ESDM relative to those in the other programs. In fact, the brain response of the ESDM-trained youngsters was identical to that of typical four-year-olds. When charting electrical brain activity with electroencephalography (EEG), the researchers noted an increase in power (the amount of energy in the signal) for certain types of brain waves known as theta oscillations in an area deep below the brain's surface called the hippocampus, the brain's memory center, so named from the Greek *hippokampos* because it resembles the shape of a seahorse. Increases in theta power have been found to correlate with more focused attention and short-term memory function.

Researchers also found a reduction in the power of alpha oscillations—which generate EEG signals that cycle up and down more quickly than theta waves—in several regions, including the hippocampus. A lower level of alpha power hints that the brain was becoming more attuned to people's faces. Increased theta and decreased alpha together reflect higher levels of electrical activity at the surface of the brain, or cerebral cortex, and specifically in the prefrontal and anterior cingulate cortices that are involved in the perception of faces. Observing these changes, the researchers conjecture that ESDM may spur brain changes in the treated children that may explain their higher scores on cognitive tests.

Research on the various early-intervention therapies for children with autism is garnering substantial scientific attention, as well it should. We should note, however, that it may be that the amount of time spent in such therapies, and not necessarily the tactic or approach administered, is what makes the difference for these youngsters. ESDM brought about these observed changes after more than 2,000 hours of intensive therapy over the course of two years, a labor of two hours twice daily for five days a week.

THE AUTHORS

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A drug that could replace or hasten this process would make a world of difference to children and their families. The latest research has started to target a range of medications that address symptoms, including impaired social communication, hyperactivity and inattention, as well as repetitive, ritualistic behaviors and sleep disturbances.

A leading prospect for a drug that could mimic the benefits of early-intervention programs is the brain hormone oxytocin, which has made headlines in the popular science press variously as the "cuddle chemical," the "moral molecule" and the "trust hormone." Known in the medical textbooks for its role in pregnancy, oxytocin readies a woman's body for childbirth. As levels rise, breasts swell and fill with milk, and later the hormone triggers labor. In the past 25 years researchers have learned that oxytocin, present in men as well, appears to play a role in promoting the bonding of infant to mother and cementing trust between friends. The hormone may even induce a sense of attachment to the baby in fathers-to-be.

Hope that oxytocin might help youngsters with autism comes from the observation that when the compound is administered in single doses either intravenously or within the nasal passages, the child with autism who normally fails to distinguish whether a new acquaintance is being "mean" or "nice" can suddenly detect the difference. Genetic studies add further evidence of oxytocin's role as a chemical that acts as a general social sensitizer and one that does so particularly in individuals with autism. Mice genetically tweaked to shut off the gene *CD38,* involved in making oxytocin, display less trust and recognition of other animals. Also, patients with autism have fewer oxytocin "receptors"—proteins that bind to oxytocin and convey its messages into specific nerve cells—and therefore lower levels of oxytocin.

These findings pave the way for larger studies. The NIH is providing $12.6 million for five institutions to conduct a trial of intranasal oxytocin in which patients are randomly assigned to a treatment or control group. The Study of Oxytocin in Autism to Improve Reciprocal Social Behaviors (SOARS-B) should determine whether oxytocin becomes a routine part of treatment. Ascertaining whether the hormone is an effective drug is especially important because a large number of parents already administer oxytocin to their children with autism. Yet the evidence so far is not conclusive enough to justify the practice. If oxytocin receives validation through this study, it might be recommended to facilitate early intervention programs by readying a child to respond to the ministrations of a therapist.

GENETIC CLUES

The long road to a cure—or at least better therapies—will require a more incisive understanding of what lies behind the mental and physical symptoms of autism. The genetic underpinnings, one of many important factors, remain largely a mystery because identifying the relevant mutations is a daunting task. Some studies suggest that an individual's predisposition is rooted in alterations in as many as 400 to 800 genes. This work finds that the disorder involves what are called copy number variants: the addition or deletion of large swathes of DNA potentially containing several genes.

Basic research into how autism develops is now trying to disentangle this complex genetic web. One of the most exciting recent genetic findings hinted that the numbingly complex genetics of autism might be less convoluted than originally thought. The project examined the genetics of 55 patients from nine Utah families who collectively turned out to have 153 copy number variants that were not present in children without autism and 185 copy number variants associated with autism from the published literature. The geneticists searched for those same copy number variants in 1,544 children with autism from the Autism Genetic Resource Exchange (AGRE) and Children's Hospital of Philadelphia (CHOP) and in 5,762 control subjects, unrelated to one another or to the children in Utah. A stringent molecular checking procedure eventually narrowed down the total to 15 familial and 31 literature copy number variants that seemed most likely to be implicated in some fashion.

More analysis is needed to clarify how the variants might contribute to autism and to explain the contribution of other nongenetic autism triggers, such as hormonal imbalances in the womb and exposure to chemicals in the environment. But important studies such as this and their ability to eliminate from consideration many of the originally targeted copy number variants provide evidence that a large number of genetic factors putatively linked to autism in the scientific literature might be ultimately ruled out.

Even with a winnowing process that reduces dramatically the number of suspect genetic elements, the possibility of finding a single autism gene that unlocks the underlying disease process in everyone will never materialize in the vast majority of cases. Most of the time at least a handful of genes are sure to be involved, each one potentially having a relatively minor role in precipitating symptoms. Many of these genes may contain so-called de novo mutations—ones that are present for the first time in the fertilized egg.

A few autism cases, however, have been shown to derive from a single disrupted gene and are proving vitally important in advancing research. Scientists are studying individuals with very rare single-gene mutations that account for about 5 percent

PHARMACOLOGY

"Cuddle Chemical" Targeted as Autism Drug

Oxytocin's ability to promote interaction with others has generated interest in using it to treat autism's social deficits. In the child with autism, oxytocin could, in theory, increase the drive to form relationships and thereby lead to a virtuous cycle (*red*) that ultimately enhances cognitive functioning. An initial verdict on the chemical's effectiveness awaits the outcome of a clinical trial now under way.

of autism cases. Exploring the psychological and molecular disorders in these children should offer clues to what goes wrong in the more common cases where multiple genes are activated in a manner that induces the symptoms of autism.

Investigators have uncovered several of these disorders that result from single-gene mutations and lead to autism, along with sets of unrelated symptoms. One prominent example is Rett syndrome, which occurs mostly in girls and impairs development of brain circuits. It leaves children with IQs that are difficult to assess and, at times, a severe form of autism that leads to the loss of any rudimentary language and basic motor skills already acquired. Research has focused on compounds that can reverse these symptoms by nourishing stunted brain circuits, among them a hormone called IGF-1, or insulinlike growth factor 1. Investigators have shown that mice with a condition resembling Rett syndrome show fewer symptoms after dosing with a compound derived from IGF-1. A small trial of the IGF-1 derivative in as many as 50 children with autism has passed initial safety testing, and work is now beginning to assess its ability to reverse symptoms.

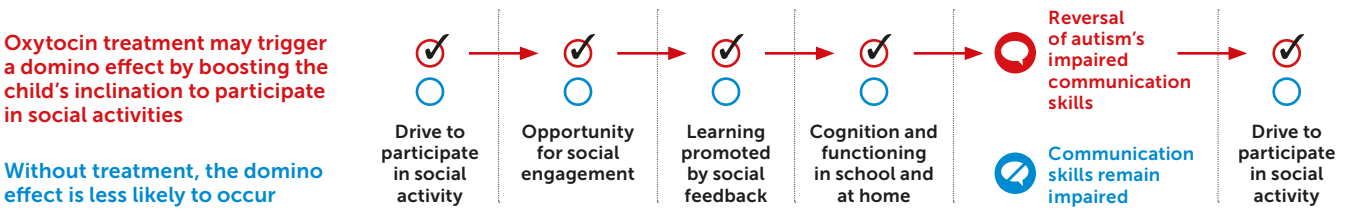
As research progresses, future studies must come to grips with the complexity of a disorder with multiple causes, differing degrees of severity, and the involvement of networks in the brain that regulate basic social behaviors and communication skills. A multipronged approach will be needed to develop ways to accurately detect the initial onset of symptoms in an 18-month-old toddler and to devise treatments that extend ultimately to correct the functioning of defective brain cells. Beyond an analysis of genetics, researchers looking for better diagnostic tools are turning to brain imaging. Studies have begun on techniques that image a few of the 40 percent of autism patients with minimal or no verbal ability in an attempt to find better criteria for diagnosing autism.

CELLULAR HELPERS

At the cellular level, researchers are manipulating stem cells in laboratory dishes with the goal of developing new treatments. Stem cells have the ability to turn into any of several cell types. First, investigators convert specialized but easily accessible cells from a patient, usually from the skin, into stem cells known as induced pluripotent stem cells [see "Your Inner Healers," by Konrad Hochedlinger; Scientific American, May 2010]. Then they treat these cells in ways that convert them into brain cells, such as neurons or supporting cells known as glia. Or they can begin with stem cells from frozen and stored umbilical cord blood of a child with autism. Now the researchers have the equivalent of neurons or glia taken from the brain of a person with autism, replete with genetic anomalies.

An analysis of the particular genetic makeup—and which genes are active in the newly minted neurons—might assist in determining where a young child could be placed on the autism spectrum, whether he or she is afflicted with a mild form of the disorder or has a severe case that will prevent the uttering of even a single word. And if the cells respond well to a particular drug—forming better connections with other cells—researchers would have reason to hope that the person might respond favorably as well. By applying such techniques, doctors may one day be able to determine which medications would best help address particular symptoms.

The longer horizon holds even more far-reaching possibilities that are today only one step removed from the realm of a science-fiction story. Consider the possibility of a cell transformed into a neuron or glial cell in the lab that holds genetic material identical to that of the donor but has perhaps been genetically altered to correct some molecular defect involved in autism. Such genetic editing methods are being applied in China and other Asian countries and have been recently approved in the U.K. In what is today a wholly theoretical scenario, a child with autism could be implanted with these stem cells and then exposed to therapeutic learning experiences, such as those provided by early intervention. This combination of genetic and behavioral therapies could then reshape the nervous system at the cellular and molecular levels and perhaps dramatically improve communication difficulties and repetitive behaviors. If such futuristic scenarios ever materialize, we may one day be able to say that we indeed are nearing a cure for children such as Adrianna and Jermaine's young Jayden. M



GRAPHIC BY SCIENTIFIC AMERICAN

MORE TO EXPLORE

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- **Autism Spectrum Disorder.** U.S. Department of Health and Human Services, National Institutes of Health, National Institute of Mental Health. NIH Publication No. QF 15-5511, Revised 2015.

FEAR NOT, CHILD

RAISE GREAT KIDS

Children with anxiety disorders can wallop their worries—and get back their life—by being encouraged to do just what they fear most. One doctor details how he helps his young patients

By
Jerry Bubrick

Illustrations By
PJ Loughran

At age 12, Julia rarely left her apartment. When she did muster the courage to go out, she first peeked out from behind the door to make sure the coast was clear.

When I first met Julia, she was the most anxious, depressed child I had ever seen. Twelve years old, she had stopped going to school and seldom left her apartment. Her eyes were big with fright. When she spoke, it was in a very soft, crackly whisper, and she would stammer, as if struggling to find words.

Julia was terrified that anyone who might see her would know instantly that something was wrong with her. When she did build up the courage to venture out, she would open the door and peek out; if she saw a neighbor in the hallway, she would close the door and wait until the coast was clear. She was not able to see friends or go anywhere comfortably, and her confinement made her feel hopeless.

Julia suffered from social anxiety, a fear that stems from a sense of being evaluated, judged and found wanting by others—and by oneself. About 1.8 million children in the U.S. suffer from clinically serious anxiety, according to the Centers for Disease Control and Prevention, with the type of anxiety tied to a child's developmental level. Separation anxiety is the most prevalent in preschool or early grade school, for example, when children typically learn to separate from attachment figures. Social anxiety tends to show up around puberty, when children become

EDITORS' NOTE: *All patient names in this article are pseudonyms.*

FAST FACTS

CONQUERING DREAD

1. About 1.8 million children in the U.S. suffer from clinically disabling anxiety.
2. Cognitive-behavioral therapy helps people recognize dysfunctional thoughts and change behaviors that reinforce harmful feelings.
3. In exposure and response prevention, a therapist helps a child face fears so he or she can habituate to them rather than avoiding or escaping them.

more tuned in to others around them.

Talk therapy, even with an experienced, dynamic clinician, was not working for Julia. She and her therapist had discussed how hard life was for her, but she was not learning why or how to make it better. In fact, talk therapy can be counterproductive for children such as Julia. Her therapist had told her to stay out of school until they could get to the bottom of her anxiety, but the longer a child is out of her social world, the harder it is for her to go back.

The best path for Julia, as I saw it, diverged dramatically from the one her previous therapist had taken. Rather than exploring the anxiety's roots, I discuss its effects. Instead of letting fears guide behavior, I change the behavior to get rid of the fear. I practice what is called cognitive-behavioral therapy (CBT) with children, and the data show that it works. In an intensive version of the therapy, I use two-hour sessions daily, or almost daily, until a patient is stable. I told Julia's parents that if they stuck with the program I was confident we could show their daughter how to regain control of her life.

UNLEARNING ANXIETY

Traditional psychotherapists view anxiety disorders as a function of unresolved issues in childhood, such as unsuccessful toilet training or disturbing sexual urges. Therapy is a process of trying to identify and resolve those past problems, which are often buried in the subconscious. Cognitive-behavioral therapists, on the other hand, believe that anxiety is caused partly by genes and partly by learned patterns of thought and behavior.

CBT is geared toward unlearning those negative habits. It is based on the hypothesis that how we think and act both can affect how we feel. By changing thinking that is distorted or dysfunctional, we can positively affect our emotional state. Moreover, if we recognize that some behaviors generate and reinforce feelings that harm us, we can lessen those emotions by changing those behaviors.

The cognitive component of CBT dates back to the 1950s, when a clinical psychologist named Albert Ellis, frustrated by the ineffectiveness of psychoanalysis, developed something he called rational emotive behavior therapy: active, goal-oriented treatment in which the therapist engages patients in identifying, challenging and replacing self-defeating thoughts and beliefs, which he called "crooked thinking." In the 1960s psychiatrist Aaron Beck of the University of Pennsylvania had also become disillusioned by psychoanalysis. Focusing on his patients' negative views, he developed what he called cognitive therapy as a way of helping them reframe such notions. The roots of the behavior-modification part of CBT emerged in the early decades of the 1900s and beyond, when pioneers in behaviorism such as Ivan Pavlov, John Watson and B. F. Skinner experimented with conditioning—linking actions to environmental stimuli—and using positive and negative reinforcement to alter behavior. The cognitive and behavioral approaches were merged in the late 1970s.

Research over more than 20 years has shown definitively that CBT is the most effective treatment for reducing symptoms of severe anxiety. In a meta-analysis (statistical review) of 48 controlled studies of CBT for anxiety in children published in 2012, clinical psychologist Shirley Reynolds, then at the University of East Anglia in England, and her colleagues determined that this form of therapy works for anxiety in kids, too, particularly if it is tailored to the type of fear the child experienced. Other researchers have shown how CBT affects the brain. In 1996 psychiatrist Jeffrey M. Schwartz of the University of California, Los Angeles, and his colleagues reported that a course of eight to 12 weeks of CBT, delivered about two hours a week, was associated with specific metabolic changes within a brain circuit thought to be involved in anxiety disorders, suggesting that the therapy is resolving symptoms by altering the function of this circuit.

We encourage kids to give the bully a name and talk back to it. Kids have called their nemesis the Witch, Mr. Bossy, Chucky, the Joker and, in the case of teenagers, names I cannot repeat.

Unfortunately, many of the children who could benefit from CBT do not receive it. This problem stems in part from a lack of experienced clinicians. In addition, many pediatricians, school psychologists and others are unaware of the benefits of the therapy and so fail to refer children. Meanwhile some doctors

THE AUTHOR

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and therapists mistakenly believe that the therapy is too tough on children when, in fact, the treatment is very gentle. We work at a child's pace, supply emotional support, and ask youngsters to do only what they are ready to do.

HIERARCHY OF FEARS

For children with anxiety disorders, the process begins by helping them, and their parents, distance themselves from the anxiety by having them conceptualize it as a bully in the brain. We encourage children to give the bully a name and talk back to it. Kids have called their nemesis the Witch, Mr. Bossy, Chucky, the Joker and, in the case of teenagers, names I cannot repeat. We explain that we are going to teach skills to handle the bully, giving children the idea that they can control their anxiety rather than letting it control them.

Another part of the process involves mapping out how the anxiety is affecting a child's life. In Julia's case, her anxiety, and desire to avoid it, was cutting her off from everything she enjoyed in her life, making her depressed. I drew a flowchart that looked something like this:

ANXIETY > ANTICIPATORY ANXIETY > AVOIDANCE > DEPRESSION

As a sixth grader, Julia had hung out with friends, gone to restaurants, played the violin and walked in the park. Now she did none of those things. A year ago she counted seven kids as her good friends; now she was down to one she saw very rarely. She was not sleeping. Julia's depression was a result of her anticipatory anxiety, a free-floating form of anxiety that someone feels when anticipating going into a situation she thinks will cause debilitating fear. If she went out in public, someone might see her, and she might be so overcome with anxiety that she would have a full-blown panic attack, in which people experience physical symptoms they misinterpret as a heart attack and worry they may be dying. (The actual symptoms are not dangerous, however.) So she avoided going out. And the avoidance only heightened and reinforced her social anxiety. Once I sketched out that chain of events, Julia got it, and I had her buying in, a little bit, to the idea that this therapy was going to be different. Her buy-in was important because the next step—facing down her fears—would depend on her trusting me.

Wearing a wig in public can constitute treatment for anxiety. Exposing children to their worst fears—whether of heights or looking foolish—helps to diminish their dread.

The core behavioral technique in the treatment of anxiety is exposure and response prevention. Adopting poet Robert Frost's claim that "the only way around is through," this method slowly and systematically helps youngsters face their fears, so they can habituate to them rather than avoiding or escaping them by continually seeking reassurance or engaging in ritualistic behaviors such as hand washing.

The first step is to identify triggers. We design a "hierarchy of fears," a series of incremental challenges, each of which is tolerable, that together amount to significant progress. Instead of thinking in black-and-white terms—I *can't* touch a dog, or I *can't* cross a bridge—kids are coaxed to consider degrees of difficulty. We might ask a child with contamination fears, for example, "On a scale of 1 to 10, how difficult would it be to touch the door handle with one finger? To touch and open the door?" For a child with a fear of vomiting, we might ask: "How difficult would it be to write the word 'vomit'?" If that challenge is a 3, to say "I will vomit today" might be a 5. To see a cartoon of someone vomiting might rate a 7. To watch a real video of someone vomiting might be considered a 9. At the top of the hierarchy most likely would be eating something the child thinks will make him or her vomit. By rating these different fears, kids come to see that some are less extreme than they had thought.

Next, we expose the child to the stressor in its mildest possible form and support him or her until the anxiety subsides. Fear, as with any sensation, diminishes over time, and children gain a sense of mastery as they feel the anxiety wane. In Julia's case, we invited a colleague she had not met to my office to have a conversation. Julia was to ask

my colleague a set series of questions. Afterward, Julia and I asked our visitor how she had done. "Did she make eye contact? Did she seem anxious to you?" Hearing, and handling, this feedback was the second part of the exposure because the feedback touched the core of her anxiety, which related to how others perceived her. Once she was comfortable interviewing a stranger in a controlled environment, we asked her to go into the hallway and approach someone and have a conversation. Again, she asked specific questions—"I'm taking a poll. What's your favorite restaurant?"—and we asked for feedback from those she polled.

To more powerfully trigger her fear of embarrassment, we asked her to be deliberately annoying by asking someone the same question repeatedly. Then, to purposely draw negative attention in a different way, we introduced a ridiculous wig. First I wore the wig, while Julia, with me, asked questions of others around the halls. Then she wore the wig and even brought some more silly wigs from home. Eventually we took coffee orders around the office and went to Starbucks, wearing the wigs.

James walked a pet banana on a leash on the sidewalk. Then we went to Grand Central Station and assigned him to ask strangers, "Where is Grand Central Station?" or "Is this the place to get trains?"

"BLAH, BLAH, I'M NOT LISTENING"

Social anxiety does not always manifest as shyness or social inhibition. It is also behind a lot of disruptive behavior that is often misinterpreted as willful aggression. One patient of mine, a 10-year-old boy named James, found himself in the emergency room after an incident that started when another boy asked him an embarrassing question. The boy said he had heard that James wanted to see a picture of one of their classmates in a bikini. James denied it, got agitated and shoved the boy. An altercation ensued; James turned into a Tasmanian devil, destroying papers and throwing things. He ended up in the vice principal's office, where he kicked the vice principal to try to get away. School officials called 911, so James could get a psychiatric evaluation.

It was not the first time James had snapped. Everyone saw him as a bully—angry, aggressive and out of control. He was banned from the cafeteria, so his parents had to take him home for lunch every day. His parents had tried therapist after therapist. Nothing was working.

We found that James was off the charts for social anxiety. He could not accept any—even constructive—criticism. He avoided even the possibility of negative feedback, which he found humiliating. When his parents asked him how his day was, he literally covered his ears and said, "Blah, blah, I'm not listening." So when the boy came to him and said, "Hey, I heard you want to see so-and-so in a bikini," even if the claim was *true*, James was so embarrassed that he freaked out.

For a child such as James or Julia, whose functioning was severely impaired, the treatment should at first involve multiple hours every day for a week or several weeks and only later consist of the typical weekly sessions. Such intensive treatment jump-starts positive change and builds a child's confidence that things *can* get better, moti-

One boy with contamination fears used hand sanitizer 50 times a day, asking his mother to wash the bottle after each use.

vating him or her to work hard. In addition, evidence suggests that the most change occurs between sessions, when patients apply the skills they have learned. When sessions are close together, kids complete the homework more consistently, resulting in faster acquisition of skills. Intensive outpatient treatment also enables families who do not have ready access to a qualified clinician to travel to one.

We treated James daily for two weeks until he was much more functional, and then he returned weekly 10 times. In addition to wearing wigs, James walked a pet banana on a leash on the sidewalk. At one point we went to Grand Central Station and assigned him to ask strangers, "Where is Grand Central Station?" or "Is this the place to get trains?" Since his treatment, he has not missed a day of school or earned a detention. He is back to eating lunch in the cafeteria, too.

Multiple studies during the past six years back up our experience that daily CBT for several weeks can reduce anxiety by at least as much as having months of weekly sessions. In a study published in 2007 psychologist Eric Storch of the University of South Florida and his colleagues found that three quarters of 20 children and adolescents shed symptoms of obsessive-compulsive disorder (OCD)—in which individuals attempt to control fears or unwanted thoughts with compulsive or ritualized actions—after 14 sessions of family-based intensive (daily) CBT. In contrast, just half of 20 youths who had received the same number of weekly treatments went into remission.

In a second trial published in 2010, Storch and his colleagues found that 14 sessions of intensive CBT led to a significant reduction in OCD symptoms, as well as associated depression and behavioral problems in 24 of 30 youths for whom medication had not worked well. Sixteen of the kids went into remission.

"IS THERE SOMETHING WRONG WITH YOUR LEGS?"

Parents also play an important role in exposure therapy. Not only do they urge their children to do their homework but they also must learn to stop doing things that enable the anxiety to grow. With the best of intentions, parents often let children avoid what they fear, sometimes even banishing words, sounds or objects that trigger a child's anxiety. Instead of making such accommodations, I advise parents to encourage a child to face her fears. For example, if Julia said, "I can't go get the mail," instead of saying, "That's okay, I'll get it," her parents were taught to challenge her. "Is there something wrong with your legs?" they might jokingly ask. If Julia really could not get the mail, her mom and dad learned to find something she *could* do, such as just opening the door or going part of the way.

Michael once even considered his siblings unsanitary. But after he was taught to sit with his anxiety until it passed, his worry waned, enabling him to eat with his family again.

In the case of Michael, an 11-year-old with severe OCD and a fear of contamination, his mother opened doors for him so that he would not have to touch the doorknob. She put his laundry in the hamper so that he could avoid touching dirty clothes. Among the things he saw as contaminated were his brother and sister. So if Michael's mom was carrying food to him and his sister walked in front of her, she threw away the food. Michael had not eaten at the table with his family for 15 months.

We explained to Michael's mother that going to such great lengths to protect Michael from his anxiety was actually reinforcing it. "Before I knew what accommodation was, I thought that I was helping," she told me. "I was devastated to know I was feeding the OCD instead."

Once I identified the accommodations Michael's mom was making, I worked with her to gradually remove them as soon as I felt Michael was ready. So instead of trying to help Michael feel safe when he was, say, anxious about touching the doorknob, she encouraged him to sit with the anxiety, knowing it would pass, and he would be able to open the door himself.

Some evidence supports the impor-

tance of parents in the process. In one study published in 2006 child psychologist Jeffrey J. Wood of U.C.L.A. and his colleagues assigned youth with anxiety disorders who were six to 13 years old to either family-focused CBT, in which parents were taught more effective communication strategies in conjunction with children's treatment, or CBT with minimal involvement from parents. The children who received the family therapy showed a 79 percent reduction in anxiety symptoms compared with a 53 percent improvement in those who had been in the therapy without parent participation.

Many anxious children can also benefit from medication, especially antidepressants, either alone or in combination with CBT. Unless a child is too impaired for CBT or the family is unwilling to do the work involved, we recommend therapy alone for the first few months to better evaluate its efficacy and then add medication when necessary. The combination of CBT and medicine has been shown to be the most effective approach for moderate to severe cases of anxiety.

ON TOP OF THE WORLD

For the first three weeks, I saw Julia three to five times a week for two hours each time. I wanted to boost her confidence and get her back out into the world. Once she was feeling more energized and the depression was fading, I gave her homework. I assigned her to go for a 10-minute walk in the park; she did not have to talk to anyone, just be outside. Then I told her to go to a restaurant to pick up a menu. One restaurant became three—later, five. Next, she had to go to Macy's and buy something. Eventually we worked on seeing friends. At first, friends visited her apartment. Later, I assigned her to go out with friends to restaurants and movies as a reintroduction to being social in the city. Our approach was the exact opposite of the one espoused by her previous therapist: stay inside until they unearthed the roots of her anxiety.

After six weeks of intensive therapy, Julia was feeling—and acting—close to her old self again, and we switched to weekly sessions. She had not returned to school, however, because she felt the environment was too demanding and critical. Julia's parents found a new school for her.

During the summer, Julia went on a family trip to Europe, armed with an action plan for her anxiety and a lifeline to us. "You can always text or call me," I told her. But I did not hear from her. When she came back, she was much happier and more confident than she had been before she left. By fall, Julia was ready for her new school. Within a few weeks there, she had started to make friends—and soon she had many. She joined the track team and got into the musical a cappella group.

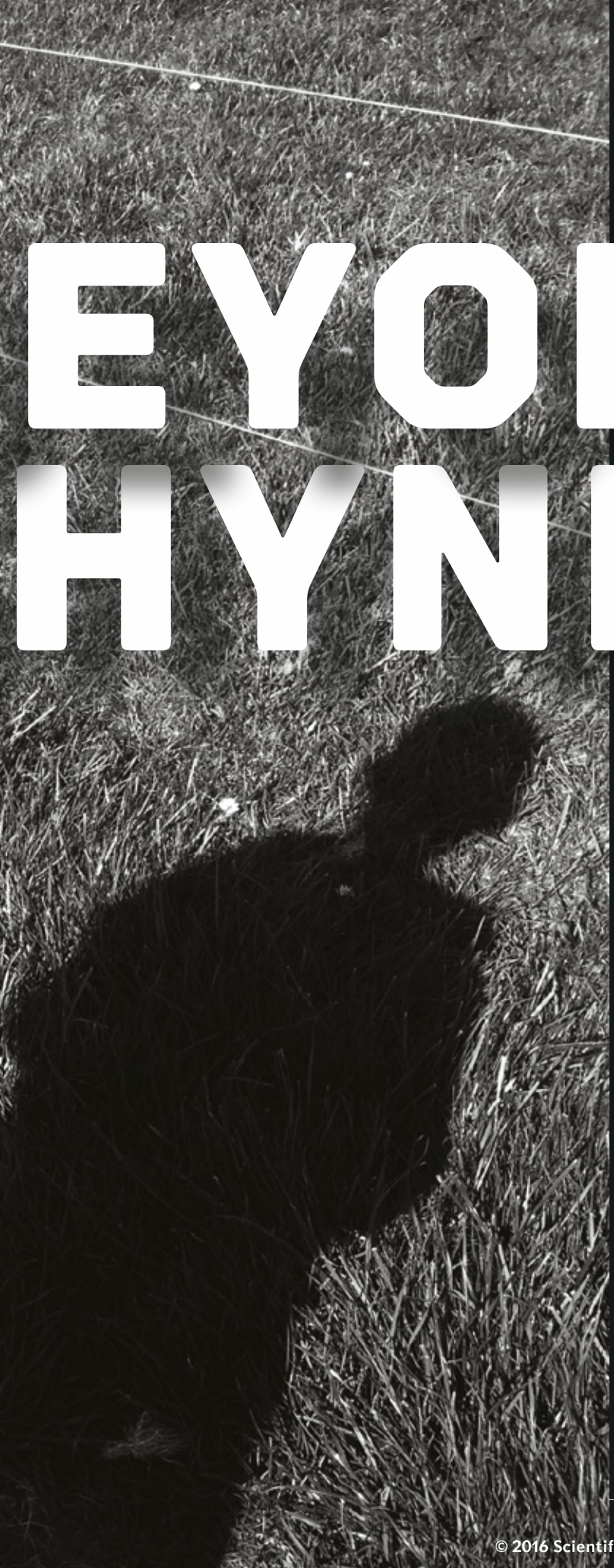
One day she returned to her old school to see her friends perform in a talent show. The lead singer of one of her friends' groups was sick, and the other members asked Julia, on the spur of the moment, to sing in her place. In front of the entire school, Julia sang an Adele song. She came out of that performance on top of the world, and the experience crystallized for her how much better her life has become after shedding her ever present apprehension.

"Time goes by so much faster," she says, "when you're not constantly dreading things." M

We explained to Michael's mother that going to such great lengths to protect Michael from his anxiety was actually reinforcing it. "Before I knew what accommodation was, I thought that I was helping," his mother said.

MORE TO EXPLORE

- **Systematic Changes in Cerebral Glucose Metabolic Rate after Successful Behavior Modification Treatment of Obsessive-Compulsive Disorder.** Jeffrey M. Schwartz et al. in *Archives of General Psychiatry,* Vol. 53, No. 2, pages 109–113; February 1996.
- **A New Look at Obsessive-Compulsive Disorder.** Melinda Wenner Moyer on ScientificAmerican.com, May 1, 2011.
- **Effects of Psychotherapy for Anxiety in Children and Adolescents: A Meta-Analytic Review.** Shirley Reynolds, Charlotte Wilson, Joanne Austin and Lee Hooper in *Clinical Psychology Review,* Vol. 32, No. 4, pages 251–262; June 2012.
- **Treating Childhood and Adolescent Anxiety: A Guide for Caregivers.** Eli R. Lebowitz and Haim Omer. John Wiley & Sons, 2013.
- To learn about CBT for anxiety disorders, visit the Anxiety and Depression Association of America's Web site: **www.adaa.org/resources-professionals/teaching-slides**



RAISE GREAT KIDS

EYOND HYNESS

That boy who never speaks in class? Chances are he has an anxiety disorder called selective mutism that demands the one thing he dreads the most: attention

By
Claudia Wallis

It is 11:30 on an August morning in New York City's Central Park Zoo—breakfast time for the sea lions. A joyful crowd oohs and aahs as trainers put the animals through their paces: catching tossed fish in midair, high-fiving with their flippers, squirting water and torpedoing around the pool. Amid the raucous throng, nine small children watch in wide-eyed silence. When a sea lion zips past at stunning speed, they do not add their voices to the squeals of delight. Some of these children are talking quietly to a camp counselor. Others sit with worried expressions that seem sadly at odds with the scene.

The nine children, ages three to six, are subdued by an anxiety disorder called selective mutism, a condition that often looks and feels like very painful shyness but with a twist. These kids will generally speak—and some will blithely chatter away—when out of the public eye and in the comforting cocoon of their own homes. But in certain settings and most typically in school, they shut down and go silent.

The zoo outing is part of a four-day program called Camp Courage, offered by the Child Study Center at New York University. It is the model for half a dozen summer camp programs for kids with selective mutism. Once thought to be extremely rare, the disorder is now believed to affect between 0.5 and 0.8 percent of youngsters—meaning there is at least one such child in most elementary schools.

These are the kids who never speak in class or whisper to only one or two confidants on the playground. They are the kindergartners who wet their pants, or worse, because they are too mortified to ask permission to use the bathroom. One child at Camp Courage accidentally hammered his thumb during a school craft project and said nothing; a teacher finally came to his aid after noticing the trail of blood.

Some children with selective mutism are outgoing, but most are not. Somewhere between half and 90 percent also suffer from social anxiety, which can cause them to pull back in settings such as a crowded playground full of unfamiliar children.

Pediatricians often dismiss the disorder, which typically emerges when a child begins preschool or kindergarten, as a passing phase that will resolve itself. In the meantime, parents get in the habit of speaking for their child, asking others to accept shrugs and gestures as communication, and explaining their youngster's "shyness" to baffled teachers and neighbors. But selective mutism does not always fade away. Survey findings and clinical experience suggest that many affected children continue to struggle for more than five years, according to child psychologist Richard Gallagher, who heads N.Y.U.'s selective mutism program. A small percentage of children remain mute into high school.

Psychologists and educators familiar with selective mutism now believe intervening to break the mute behavior pattern is important so that it does not compromise a child's academic, social and psychological development. That belief is in keeping with a broader trend toward early intervention in other childhood conditions that affect learning and socialization, such as attention-deficit/hyperactivity disorder, communication disorders and autism. Selective mutism is less well recognized, however, and many kids who would benefit from therapy either receive the wrong kind or none at all. Only in the past few years has rigorous research validated a therapeutic approach to selective mutism. At the same time, scientists are beginning to explore the mysterious—and in some cases, surprising—roots of this once obscure disorder.

NAMING THE SILENCE

Spend a few days around children who have selective mutism, and you begin to wonder if they have a hidden on/off switch. In the large, airy classroom where Camp Courage convened, I saw a

FAST FACTS

STRUCK SPEECHLESS

1. Selective mutism, a disorder that leaves individuals too anxious to speak in certain contexts (usually school), is now believed to affect between 0.5 and 0.8 percent of young children.
2. Evidence suggests that genetics plays a significant role in the disorder. Issues with auditory processing may also contribute.
3. Therapies focus on gradually increasing a child's exposure to speaking in distressing situations and providing rewards for braving his or her fears.

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child stop a conversation in its tracks the minute an unfamiliar therapist tried to join in. Conversely, a boy who had been largely silent all day got into an elevator with his mom at pickup time and began a perfectly ordinary chat about where she had parked the car.

Because these kids are capable of speaking normally, their mute behavior can look willful. In 1877, when German physician Adolph Kussmaul penned what may be the earliest description of selective mutism, he named it *aphasia voluntaria* (Latin for a "voluntary lack of speech"). In keeping with the idea that the child has chosen silence, psychiatrists called the disorder elective mutism when it first appeared in the *Diagnostic and Statistical Manual of Mental Disorders* (*DSM*) in 1980. The name changed

Kids with the disorder tend to be self-conscious and fretful about making mistakes. "They react to speaking as if it were a performance," says psychologist R. Lindsey Bergman of U.C.L.A.

ARIEL SKELLEY *Corbis*

in the 1994 edition after research and clinical experience made it clearer that selective mutism was driven more by anxiety than defiance. The current edition (*DSM-5*), published in 2013, classifies selective mutism as a unique childhood anxiety disorder marked by a failure to speak in certain settings that cannot be explained by communication or language difficulties [*see box above*].

Most children who are treated for selective mutism are also diagnosed with an additional anxiety disorder. Usually this is social anxiety disorder, which involves grave distress in social settings and often a paralyzing fear of making a social mistake. Although most socially anxious kids are withdrawn but not mute, more than half and perhaps as many as nine out of 10 selectively mute children also suffer from social anxiety. A number of clinicians regard selective mutism as a subtype of this disorder.

Despite its sometimes dramatic symptoms, selective mutism is often overlooked. In 2002 R. Lindsey Bergman, a child psychologist at the University of California, Los Angeles, studied the prevalence of this disorder among 2,256 kindergartners and first and second graders in a large California school district. She noted that most of the children who matched *DSM* criteria for the disorder (based on detailed input from their teachers) had not been previously identified. "Teachers just think the kids are super, super shy," Bergman says. "And at this age, the teacher is more worried about the child who is acting out and not staying in his seat."

Another common issue is mislabeling. In her clinical practice, Bergman has seen youngsters with selective mutism who have been incorrectly diagnosed with a speech and language problem or an autism spectrum disorder. Sue Newman, co-director of the Selective Mutism Foundation, says that she frequently hears about misdiagnosed children who have been placed in educational settings designed for kids with autism or speech disorders that not only fail to address their mutism but may make them feel more self-conscious and anxious.

Even when the problem is correctly diagnosed, finding help (and a qualified therapist who accepts health insurance) is a challenge. According to Britanny Roslin, who is one of three N.Y.U. child psychologists at Camp Courage, "a lot of clinicians don't want to work with these kids, because they don't know what to do. You can be sitting across from a kid for years without speaking."

Selective Mutism in the *DSM-5*

Five diagnostic criteria distinguish the disorder:

- ☐ The child consistently fails to speak in certain settings.
- ☐ The problem has lasted at least a month (not including the first month of school).
- ☐ The issue cannot be fully explained by a communication disorder.
- ☐ The condition interferes with the child's education or social communication.
- ☐ The child's silence cannot be attributed to an unfamiliarity with spoken language.

WHY THEY GO QUIET

A child's mute behavior can come as a shock. Susan* still gets emotional recalling events on her son's third day of kindergarten when a teacher came up to her spouse at pickup time and cheerily asked, "So, is he ever going to start talking?" Evan* was exuberant and verbal at home and had been vocal during three years of preschool. "We were totally flabbergasted," she remembers. "We were both up all night." Only in hindsight did they see the warning signs: Evan's refusal to say hello to waiters, store clerks and adult neighbors. The couple, who live in New York City, recognized their son's symptoms from online descriptions of selective mutism and quickly made contact with N.Y.U.'s program.

Clinicians who work with kids with the disorder say that parents often describe their kids as having been cautious and socially reticent since infancy. These

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characteristics—what psychologists call a behaviorally inhibited temperament—are typical of 15 to 20 percent of babies and toddlers. "They are hesitant to interact with peers—they withdraw from social situations and are highly vigilant," says developmental psychologist Nathan Fox of the University of Maryland. Although most go on to be perfectly fine, behaviorally inhibited children have a 30 percent increased risk of developing an anxiety disorder, especially social anxiety.

As with most psychiatric disorders, the causes of selective mutism are not well understood, but a genetic component seems likely. Studies have found that anxiety disorders of various types tend to run in the families of affected kids. Bergman says, "When I see parents of kids with selective mutism, about 75 percent of the time I can say, 'Which one of you was like this as a kid?' and one will say they either did not speak in class or sat there in fear that they would be called on."

A 2011 study involving 106 children with the disorder offers a hint to its genetic origins. University of California, San Diego, psychiatrist Murray Stein and his colleagues found preliminary evidence that a variation in a gene called *CNTNAP2* raises the risk of the disorder. The study also discovered that the same gene variation was associated with symptoms of social anxiety in a group of 1,028 young adults. The *CNTNAP2* gene codes for a protein that is produced in the developing cortex of the brain and plays a role in brain cell connectivity. Intriguingly, variants of the gene have been implicated in autism and certain language impairments—findings that suggest the gene might have a part in a variety of social and communication disorders.

One research group in Israel has found evidence that many children with selective mutism have a hearing abnormality that affects the way they perceive their own voice. In a series of small studies published between 2004 and 2013 involving a total of 75 subjects with selective mutism, psychologist Yair Bar-Haim of Tel Aviv University and his collaborators found that roughly 50 percent of affected children have some kind of problem with their "efferent" auditory system. This system—which involves the middle ear, brain stem and cerebral cortex—normally attenuates the sound of one's own voice, which, as Bar-Haim says, is otherwise loudly "bone-conducted directly into our own brain." Quieting down our voice helps us tune into our environment while speaking. Bar-Haim's findings could help explain why some children with this disorder complain that their voice sounds funny or loud to them. If he is correct, then treating anxiety alone will be insufficient for many cases of selective mutism.

Teachers usually play an important role in helping a child conquer selective mutism. A therapist may coach them to gently nudge a student from nonverbal participation in class to brief, whispered answers to full engagement—with rewards for progress.

MIKA *Corbis*

Indeed, numerous factors can contribute to anxiety about speaking. According to osteopathic physician Elisa Shipon-Blum, director of the Selective Mutism Anxiety Research and Treatment Center in Jenkintown, Pa., developmental delays, learning disabilities, speech and language issues, and sensory processing challenges can cause a child to shut down in a noisy, overstimulating classroom. "We may see a deficit in their narrative skills—their ability to tell a story, to tell you what they read in a book or what a movie is about," Shipon-Blum says.

For the most part, children who have selective mutism are too young to offer their own explanations for their behavior, but a preoccupation with making verbal or social mistakes seems to be central for many. Danica Cotov, a recent college graduate from New Jersey who struggled with mutism for 16 years, gives this account: "I lived in constant fear of being judged by my peers, who I was certain would think negatively of me. I had a constant stream of thoughts and worries running through my head." After years of silence, she dreaded the fuss that would be made if she ever did speak up.

FINDING HELP

At Camp Courage, each of the nine children was working toward a specific goal. For Cindy,* an elfin girl with big, brown eyes and a honey-colored braid, it was to use her "full voice" instead of a whisper. Evan was working on allowing anyone besides Gallagher, with whom he chatted easily, to hear his voice. Campers earned points by participating in group games such as Go Fish that required simple, predictable utterances ("Do you have any zebras?"). At the end of each day, they could pick a big or

small prize depending on how many points they had racked up.

Psychologists at N.Y.U. and elsewhere typically treat selective mutism with a modified version of therapies shown to be effective for other anxiety disorders and phobias. First they encourage kids to speak with parents in a clinical setting and eventually to speak with the therapist. In close collaboration with teachers, they gradually move the child through a hierarchy of behaviors—from nonverbal exchanges to mouthing words to whispering and then using a full voice—in circumstances where he or she would ordinarily be mute. They also work on widening the circle of people to whom the child will speak. At school, for example, teachers may be coached to permit silent nods, then one-word answers prompted by simple, limited-choice questions (such as "Is the answer 5 or 7?"). Along the way, kids earn rewards for speaking up. The idea is that gradual exposure to speaking will defang their fears.

In 2013 Bergman and her colleagues published a study on this type of treatment. She divided 21 children with selective mutism, ages four to eight, into two groups. One group was placed on a 12-week waiting list. The other group received 24 weeks of an intervention that included 20 hour-long private sessions with a therapist and assignments designed to gradually increase the child's exposure to speaking in feared settings—mainly school. Therapists worked closely with teachers and parents, who were taught how to continue to help the child once the experiment was over. Independent evaluators, who did not know which kids had the intervention, rated their progress.

After 12 weeks, a quarter of the children receiving treatment showed major improvement, whereas none on the waiting list improved. After completing the full 24 weeks of therapy, 75 percent of the treated children had progressed in their speaking behaviors, and two thirds of them no longer met the criteria for selective mutism. Three months later they were found to have maintained their progress. Aside from a small-scale drug study published in 1994, Bergman's research appears to be the first ever randomized controlled study of a therapy for the condition.

GETTING RESULTS

In Gallagher's experience, the children who respond fastest to therapy are those who are social, despite the disorder. "They look like they want to be involved with other kids," he says. "They play, they use a lot of gestures, they have friends." More challenging are those who have some features of autism and lack motivation to engage with others, and youngsters with symptoms of a broader social anxiety who appear distressed or uncomfortable even when playing. Several studies have shown that some children improve when given a selective serotonin reuptake inhibitor such as Prozac, which reduces anxiety. Adding elements of cognitive-behavioral therapy can help older kids learn to use reason to make their fears seem more manageable.

When school got under way last fall, Cindy's parents were pleased with her progress. "She's initiating conversation with her teacher," her mother says. "That didn't happen last year." For Evan, progress is slower. "When we walk into school, he's saying, 'Hey, everybody,' to the kids and has his rambunctious, easygoing personality," Susan reports. "Then when we say, 'Gotta go, have a great day, love you,' that's when he stops talking. He's missing out on so much of school, and [his teachers] are missing out on so much of him."

Few studies have followed children with selective mutism throughout childhood and adolescence, so no one can say with authority how long the disorder typically lasts, what percentage will remain socially anxious or what traits predict a good outcome. One point does seem clear: training teachers, special education personnel, and speech and language specialists to better recognize selective mutism and to intervene more effectively could help many children. Once they have begun to speak, most remain timid, but for others, Bergman says, "it's almost like they've had the flu. They go on to be the most gregarious people, and you can imagine that years later their families will say, 'Oh, my gosh, remember when Mary didn't talk?'" M

Some kids go on to become quite gregarious, Bergman says. She can imagine their families saying years later, "Oh, my gosh, remember when Mary didn't talk?"

*NOT THEIR REAL NAMES

MORE TO EXPLORE

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IS DIVORCE BAD FOR CHILDREN?

The breakup may be painful, but most kids adjust well over time

By
Hal Arkowitz and Scott O. Lilienfeld

Many of the 1.5 million children in the U.S. whose parents divorce every year feel as if their world is falling apart. Divorcing parents are usually very concerned about the welfare of their children during this troublesome process. Some parents are so worried that they remain in unhappy marriages, believing it will protect their offspring from the trauma of divorce.

Yet parents who split have reasons for hope. Researchers have found that only a relatively small percentage of children experience serious problems in the wake of divorce or, later, as adults.

RAPID RECOVERY

Divorce affects most children in the short run, but research suggests that kids recover rapidly after the initial blow. In a 2002 study psychologist E. Mavis Hetherington of the University of Virginia and her then graduate student Anne Mitchell Elmore found that many children experience short-term negative effects from divorce, especially anxiety, anger, shock and disbelief. These reactions typically diminish or disappear by the end of the second year. Only a minority of kids suffer longer.

Most children of divorce also do well in the longer term. In a quantitative review of the literature in 2001, sociologist Paul R. Amato, then at Pennsylvania State University, examined the possible effects on children several years after a divorce. The studies compared children of married parents with those who experienced divorce at different ages. The investigators followed these kids into later childhood, adolescence or the teenage years and assessed their academic achievement, emotional and behavior problems, delinquency, self-concept and social relationships. On average, the studies found only very small differences on all these measures between children of divorced parents and those from intact families, suggesting that the vast majority of children endure divorce well.

Researchers have consistently found that high levels of parental conflict during and after a divorce are associated with poorer adjustment in children. The effects of conflict before the separation, however, may be the reverse in some cases. In a 1985 study Hetherington and her associates reported that some children who are exposed to high levels of

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marital discord prior to divorce adjust better than those who experience low levels. Apparently when marital conflict is muted, children are often unprepared when told about the upcoming divorce. They are surprised, perhaps even terrified, by the news. In addition, children from high-discord families may experience the divorce as a welcome relief from their parents' fighting.

Taken together, the findings suggest that only a small percentage of young people experience divorce-related problems. Even here the causes of these lingering difficulties remain uncertain. Some troubles may arise from conflict between Mom and Dad associated with the divorce. The stress of the situation can also cause the quality of parenting to suffer. Divorce frequently contributes to depression, anxiety or substance abuse in one or both parents and may bring about difficulties in balancing work and child-rearing. These problems can impair a parent's ability to offer children stability and love when they are most in need.

GROWN-UP CONCERNS

The experience of divorce can also create problems that do not appear until the late teenage years or adulthood. In 2000 in a book entitled *The Unexpected Legacy of Divorce: A 25 Year Landmark Study,* the late Judith Wallerstein, then at the University of California, Berkeley, and her colleagues presented detailed case studies suggesting that most adults who were children of divorce experience serious problems such as depression and relationship issues.

Yet scientific research does not support the view that problems in adulthood are prevalent; it instead demonstrates that most children of divorce become well-adjusted adults. For example, in a 2002 book, *For Better or For Worse: Divorce Reconsidered,* Hetherington and her co-author, journalist John Kelly, describe a 25-year study in which Hetherington followed children of divorce and children of parents who stayed together. She found that 25 percent of the adults whose parents had divorced experienced serious social, emotional or psychological troubles compared with 10 percent of those whose parents remained together. These findings suggest that only 15 percent of adult children of divorce experience problems over and above those from stable families. No one knows whether this difference is caused by the divorce itself or by variables, such as poorer parenting, that often accompany a marriage's dissolution.

Children who are good problem solvers and seek support are more resilient than those who rely on distraction and avoidance.

In a review article in 2003, psychologists Joan B. Kelly of Corte Madera, Calif., and Robert E. Emery of the University of Virginia concluded that the relationships of adults whose parents' marriages failed do tend to be somewhat more problematic than those of children from stable homes. For instance, people whose parents split when they were young experience more difficulty forming and sustaining intimate relationships as young adults, greater dissatisfaction with their marriages, a higher divorce rate and poorer relationships with the noncustodial father compared with adults from sustained marriages. On all other measures, differences between the two groups were small.

BOUNCING BACK

Even though children of divorce generally do well, a number of factors can reduce the problems they might experience. Children fare better if parents can limit conflict associated with the divorce process or minimize kids' exposure to it. Further, children who live in the custody of at least one well-functioning parent do better than those whose primary parent is doing poorly. In the latter situation, the maladjusted parent should seek professional help or consider limiting his or her time with the child. Parents can also support their children during this difficult time by talking to them clearly about the divorce and its implications and answering their questions fully.

Other, more general facets of good parenting can also buffer against divorce-related difficulties in children. Parents should provide warmth and emotional support, and they should closely monitor their children's activities. They should also deliver discipline that is neither overly permissive nor overly strict. Other factors contributing to children's adjustment include postdivorce economic stability and social support from peers and other adults, such as teachers.

In addition, certain characteristics of the child can influence his or her resilience. Children with an easygoing temperament tend to fare better. Coping styles also make a difference. For example, children who are good problem solvers and who seek social support are more resilient than those who rely on distraction and avoidance.

The good news is that although divorce is hard and often extremely painful for children, long-term harm is not inevitable. Most will bounce back and get through this difficult situation with few if any battle scars. M

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RAISE GREAT KIDS

THE AMAZING TEEN BRAIN

By Jay N. Giedd

A mismatch in the maturation of brain networks leaves adolescents open to risky behavior but also allows for leaps in cognition and adaptability

Illustration By Harry Campbell

Photograph By Ethan Hill

The "teen brain" is often ridiculed as an oxymoron—an example of biology gone wrong.

Neuroscientists have explained the risky, aggressive or just plain baffling behavior of teenagers as the product of a brain that is somehow compromised. Groundbreaking research in the past 10 years, however, shows that this view is wrong. The teen brain is not defective. It is not a half-baked adult brain, either. It has been forged by evolution to function differently from that of a child or an adult.

Foremost among the teen brain's features is its ability to change in response to the environment by modifying the communications networks that connect brain regions. This special changeability, or plasticity, is a double-edged sword. It allows teenagers to make enormous strides in thinking and socialization. But the morphing landscape also makes them vulnerable to dangerous behaviors and serious mental disorders.

The most recent studies indicate that the riskiest behaviors arise from a mismatch between the maturation of networks in the limbic system, which drives emotions and becomes turbo-boosted in puberty, and the maturation of networks in the prefrontal cortex, which occurs later and promotes sound judgment and the control of impulses. Indeed, we now know that the prefrontal cortex continues to change prominently until well into a person's 20s. And yet puberty seems to be starting earlier, extending the "mismatch years."

The plasticity of networks linking brain regions—and not the growth of those regions, as previously thought—is key to eventually behaving like an adult. Understanding that, and knowing that a widening gap between the development of emotional and judgment networks is happening in young people today, can help parents, teachers, counselors and teenagers themselves. People will better see that behaviors such as risk taking, sensation seeking, and turning away from parents and toward peers are not signs of

cognitive or emotional problems. They are a natural result of brain development, a normal part of adolescents learning how to negotiate a complex world.

The same understanding can also help adults decide when to intervene. A 15-year-old girl's departure from her parents' tastes in clothing, music or politics may be a source of consternation for Mom and Dad but does not indicate mental illness. A 16-year-old boy's propensity to skateboard without a helmet or to accept risky dares from friends is not trivial but is more likely a manifestation of short-range thinking and peer pressure than a desire to hurt himself. Other exploratory and aggressive actions might be red flags, however. Knowing more about the unique teen brain will help all of us learn how to separate unusual behavior that is age-appropriate from that which might indicate illness. Such awareness could help society reduce the rates of teen addiction, sexually transmitted diseases, motor vehicle accidents, unwanted pregnancy, homicide, depression and suicide.

GREATER CONNECTIVITY

Few parents of a teenager will be surprised to hear that the brain of a 16-year-old is different from the brain of an eight-year-old. Yet researchers have had difficulty pinning down these differences in a scientific way. Wrapped in a tough, leathery membrane, surrounded by a protective moat of fluid and completely encased in bone, the brain is well protected from falls, attacks from predators—and the curiosity of scientists.

The invention of imaging technologies such as computerized tomography and positron-emission tomography has offered some progress, but because these techniques emit ionizing radiation, it was unethical to use them for exhaustive studies of youth. The advent of magnetic resonance imaging (MRI) finally provided a way to lift the veil, offering a safe and accurate way to study the anatomy and physiology of the brain in people of all ages. Ongoing studies are tracking thousands of twins and single individuals throughout their lives. The consistent theme that is emerging is that the adolescent brain does not mature by getting larger; it matures by having its different components become more interconnected and by becoming more specialized.

In MRI scans, the increase in connectivity among brain regions is indicated as greater volumes of white matter. The "white" in white matter comes from a fatty substance called myelin, which wraps and insulates the long wire, or axon, that extends from a neuron's body. Myelination—the formation of this fatty sheath—takes place from childhood through adulthood and significantly speeds up the conduction of nerve impulses among neurons. Myelinated axons transmit signals up to 100 times faster than unmyelinated ones.

Myelination also accelerates the brain's information processing by helping axons recover quickly after they fire so that they are ready to send another message. Quicker recovery time allows up to a 30-fold increase in the frequency with which a given neuron can transmit information. The combination of faster transmission and shorter recovery time provides a 3,000-fold increase in the brain's computational bandwidth between infancy and adulthood, permitting extensive and elaborate networking among brain regions.

Recent investigations are revealing another, more nuanced role for myelin. Neurons integrate information from other neurons but only fire to pass it on if the incoming input exceeds a certain electrical threshold. If the neuron fires, that action initiates a series of molecular changes that strengthens the synapses, or connections, between that neuron and the input neurons.

This strengthening of connections forms the basis for learning. What researchers themselves are now learning is that for input from nearby and distant neurons to arrive simultaneously at a given neuron, the transmission must be exquisitely timed, and myelin is intimately involved in the fine-tuning of this timing. As children become teenagers, the rapid expansion of myelin increasingly joins and coordinates activities in different parts of the brain on a variety of cognitive tasks.

Scientists can now measure this changing interconnectivity by applying graph theory, a type of mathematics that quantifies the relation between "nodes" and "edges" in a network. Nodes can be any object or detectable entity—a neuron or a brain structure such as the hippocampus or a larger region such as the prefrontal cortex. Edges can be any connections among nodes, from a physical connection such as a synapse between neurons to a statistical correlation such as when two parts of the brain are activated similarly during a cognitive task.

Graph theory has helped me and others to measure how different brain regions develop and become interconnected to one another and to correlate such features with changes in behavior and cognition. Brain changes are not confined to adolescence. Most brain circuits develop in the womb, and many continue to change throughout life, well beyond the teen years. It turns out, however, that during that period there is a dramatic increase in connectivity among brain regions involved in judgment, getting along with others and long-range

FAST FACTS

ONE-OF-A-KIND MIND

1. MRI studies show that the teenage brain is not an old child brain or a half-baked adult brain; it is a unique entity characterized by changeability and an increase in networking among brain regions.
2. The limbic system, which drives emotions, intensifies at puberty, but the prefrontal cortex, which controls impulses, does not mature until the 20s. This mismatch makes teens prone to risk taking but also allows them to adapt readily to their environment.
3. Earlier onset of puberty in children worldwide is expanding the years during which the mismatch occurs.
4. Greater understanding of the teen brain should help parents and society better distinguish typical behavior from mental illness while helping teens become the people they want to be.

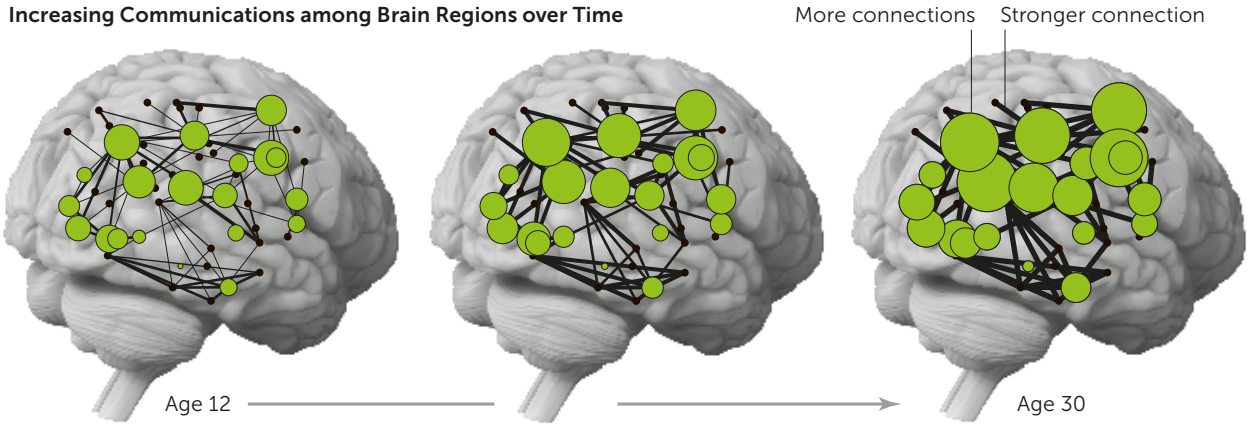
PAGE 92: PHOTOGRAPH FOR ILLUSTRATION PURPOSES ONLY

A NEW VIEW

Greater Networking Brings Maturity

The most significant change taking place in an adolescent brain is not the growth of brain regions but the increase in communications among groups of neurons. When an analytical technique called graph theory is applied to data from MRI scans, it shows that from ages 12 to 30, connections between certain brain regions or neuron groups become stronger (*black lines that get thicker*). The analysis also shows that certain regions and groups become more widely connected (*green circles that get larger*). These changes ultimately help the brain to specialize in everything from complex thinking to being socially adept.

Increasing Communications among Brain Regions over Time



DAVID KILLPACK (*brains*) AND JEN CHRISTIANSEN (*nodal diagrams*); SOURCE: "DEVELOPMENT OF BRAIN STRUCTURAL CONNECTIVITY BETWEEN AGES 12 AND 30: A 4-TESLA DIFFUSION IMAGING STUDY IN 439 ADOLESCENTS AND ADULTS," BY EMILY L. DENNIS ET AL., IN *NEUROIMAGE*, VOL. 64; JANUARY 1, 2013 (SUPPLEMENTARY VIDEO 2)

planning—abilities that profoundly influence the remainder of a person's life.

TIME TO SPECIALIZE

As the white matter along neurons is developing with age in adolescents, another change is taking place. Brain development, like other complex processes in nature, proceeds by a one-two punch of overproduction, followed by selective elimination. Like Michelangelo's *David* emerging from a block of marble, many cognitive advances arise during a sculpting process in which unused or maladaptive brain cell connections are pruned away. Frequently used connections, meanwhile, are strengthened. Although pruning and strengthening occur throughout our lives, during adolescence the balance shifts to elimination, as the brain tailors itself to the demands of its environment.

Specialization arises as unused connections among neurons are eliminated, decreasing the brain's gray matter. Gray matter consists largely of unmyelinated structures such as neuron cell bodies, dendrites (antennalike projections from the cells that receive information from other neurons) and certain axons. Overall, gray matter increases during childhood, reaches a maximum around age 10 and declines through adolescence. It levels off during adulthood and declines somewhat further in senescence. The pattern also holds for the density of receptor cells on neurons that respond to neurotransmitters—molecules such as dopamine, serotonin and glutamate that modulate communication among brain cells.

Although the raw amount of gray matter tops out around puberty, full development of different brain regions occurs at different times. Gray matter, it turns out, peaks earliest in what are called primary sensorimotor areas devoted to sensing and responding to sight, sound, smell, taste and touch. It peaks latest in the prefrontal cortex, crucial to executive functioning, a term that encompasses a broad array of abilities, including organization, decision making and planning, along with the regulation of emotion.

An important feature of the prefrontal cortex is the ability to create hypothetical what-ifs by mental time travel—to consider past, present and possible future outcomes by running simulations in our mind instead of subjecting ourselves to potentially dangerous reality. As philosopher Karl Popper phrased it, instead of putting ourselves in harm's way, "our theories die in our stead." As we mature cognitively, our executive functioning also makes us more likely to choose larger, longer-term rewards over smaller, shorter-term ones.

The prefrontal cortex is also a key component of circuitry involved in social cognition—our ability to navigate complex social relationships, discern friend from foe, find protection within groups and carry out the prime directive of adolescence: to attract a mate.

Adolescence is therefore marked by changes in gray matter and in white matter that together transform the networking among brain regions as the adult brain takes shape. The prefrontal cortex functions are not absent in teenagers; they are just not as good as they are going to get. Because they do not fully mature until a person's 20s, teens may have trouble controlling impulses or judging risks and rewards.

A MISMATCH IN MATURATION

Unlike the prefrontal cortex, the hormone-fueled limbic system undergoes dramatic changes at the time of puberty,

which traditionally begins between ages 10 and 12. The system regulates emotion and feelings of reward. It also interacts with the prefrontal cortex during adolescence to promote novelty seeking, risk taking and a shift toward interacting with peers. These behaviors, deeply rooted in biology and found in all social mammals, encourage tweens and young teens to separate from the comfort and safety of their families to explore new environments and seek outside relationships. These behaviors diminish the likelihood of inbreeding, creating a healthier genetic population, but they can also pose substantial dangers, especially when mixed with modern temptations such as easy access to drugs, firearms and high-speed motor vehicles, unchecked by sound judgment.

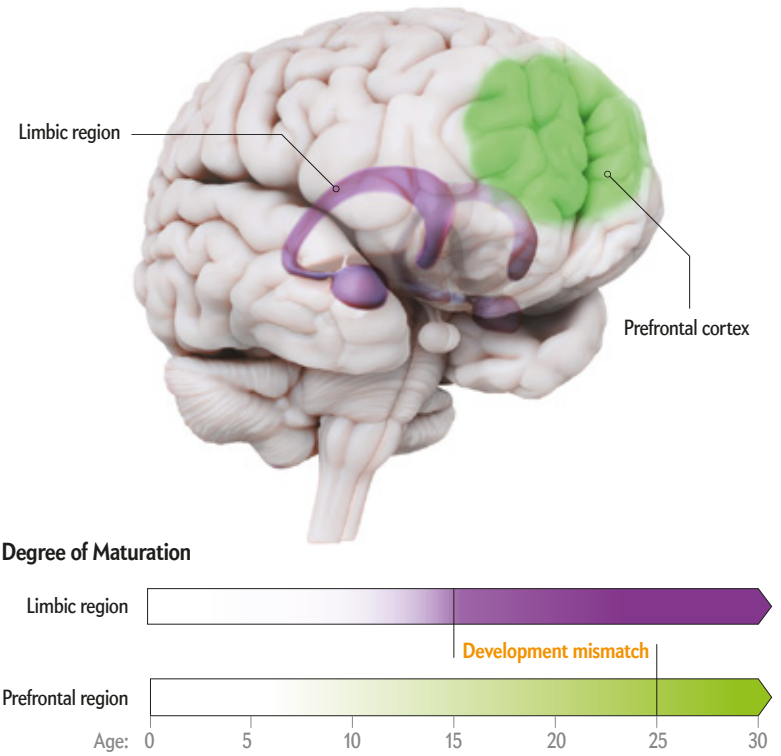
What most determines teen behavior, then, is not so much the late development of executive functioning or the early onset of emotional behavior but a mismatch in the timing of the two developments. If young teens are emotionally propelled by the limbic system, yet prefrontal control is not as good as it is going to get until, say, age 25, that leaves a decade of time during which imbalances between emotional and contemplative thinking can reign. Furthermore, puberty starting at an earlier age, as is the case worldwide, lengthens the gap of time between the onset of increased risk taking and sensation seeking and the rise of a strong, stabilizing prefrontal cortex.

The lengthening mismatch supports the growing notion that the teen years are no longer synonymous with adolescence. Adolescence, which society defines as the transition from childhood to adulthood, begins in biology with the onset of puberty but ends in a social construct when a person achieves independence and assumes adult roles. In the U.S., attainment of an adult role—often characterized by such events as getting married, having a child and owning a home—is occurring approximately five years later than in the 1970s.

ROOTS OF RISK TAKING

Emotion vs. Control

Teenagers are more likely than children or adults to engage in risky behavior, in part because of a mismatch between two major brain regions. Development of the hormone-fueled limbic system (*purple*), which drives emotions, intensifies as puberty begins (typically between ages 10 to 12), and the system matures over the next several years. But the prefrontal cortex (*green*), which keeps a lid on impulsive actions, does not approach full development until a decade later, leaving an imbalance during the interim years. Puberty is starting earlier, too, boosting hormones when the prefrontal cortex is even less mature.



DAVID KILLPACK (*brain*) AND JEN CHRISTIANSEN (*graphic*); SOURCE: JAY N. GIEDD

The large influence of social factors in determining what constitutes an adult has led some psychologists to suggest that adolescence is less of a biological reality than a product of changes in child-rearing since the industrial revolution. Yet twin studies, which examine the relative effects of genes and environment by following twins who have different experiences, refute the view that social factors can substantially override the biology. They show that the pace of biological maturation of white and gray matter can be influenced somewhat by the environment but that the fundamental timing is under biological control. Sociologists see this, too: risk taking, sensation seeking and a move toward peers happen in all cultures, although the degree can vary.

VULNERABILITY AND OPPORTUNITY

The gray matter, white matter and networking developments detected by MRI underscore the observation that the most striking feature in teen brain development is the extensive changes that occur. In general, this plasticity decreases throughout adulthood, and yet we hu-

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mans still retain a level of plasticity far longer than any other species.

Protracted maturation and prolonged plasticity allow us to "keep our options open" in the course of our own development, as well as the entire species' evolution. We can thrive everywhere from the frigid North Pole to hot islands on the equator. With technologies developed by our brain, we can even live in vessels orbiting our planet. Back 10,000 years ago—a blink of an eye in evolutionary terms—we spent much of our time securing food and shelter. Today many of us spend most of our waking hours dealing with words and symbols—which is particularly noteworthy, given that reading is only 5,000 years old.

Prolonged plasticity has served our species well but creates vulnerabilities in addition to opportunities. Adolescence is the peak time of emergence for several types of mental illnesses, including anxiety disorders, bipolar disorder, depression, eating disorders, psychosis and substance abuse. Surprisingly, 50 percent of the mental illnesses people experience emerge by age 14, and 75 percent start by age 24.

The relation between typical adolescent brain changes and the onset of psychopathology is complicated, but one underlying theme may be that "moving parts get broken." The idea is that the extensive changes in white matter, gray matter and networking increase the chance for problems to arise. For example, almost all the abnormal brain findings in adult schizophrenia resemble the typical changes of adolescent brain development gone too far.

In many other ways, adolescence is the healthiest time of life. The immune system, resistance to cancer, tolerance to heat and cold, and other traits are at their greatest. Despite physical robustness, however, serious illness and death are 200 to 300 percent higher for teens than for children. Motor vehicle accidents, the number-one cause, account for about half of teen deaths. Homicide and suicide rank second and third. Unwanted teen pregnancy, sexually transmitted diseases and behavior leading to incarceration are also high, imposing tough, lifelong consequences.

So what can doctors, parents, teachers and teens themselves do about these pitfalls? For clinicians, the paucity of novel medications in psychiatry and the propensity of the adolescent brain to respond to environmental challenges suggest that nonmedication interventions may be most fruitful—especially early in teen development, when white matter, gray matter and networking are changing fast. Treatment of obsessive-compulsive disorder is one example; behavioral interventions that trigger the obsessive impulse but gradually modify a person's response may be highly effective and could prevent a lifetime of disability. Appreciating that the brain is changeable throughout the teen years obliterates the notion that a youth is a "lost cause." It offers optimism that interventions can change a teenager's life course.

More study will help, too. The infrastructure for adolescent research is not well developed, funding for this work is meager and few neuroscientists specialize in this age group. The good news is that as researchers clarify the mechanisms and influences of adolescent brain developments, more resources and scientists are being drawn into the field, eager to minimize risks for teenagers and harness the incredible plasticity of the teen brain.

Understanding that the adolescent brain is unique and rapidly changing can help parents, society and teens themselves to better manage the risks and grasp the opportunities of the teenage years. Knowing that prefrontal executive functions are still under construction, for example, may help parents to not overreact when their daughter suddenly dyes her hair orange and instead take solace in the notion that there is hope for better judgment in the future. Plasticity also suggests that constructive dialogue between parents and teens about issues such as freedoms and responsibilities can influence development.

Adolescents' inherent capacity to adapt raises questions about the impact of one of the biggest environmental changes in history: the digital revolution. Computers, video games, cell phones and social media have in the past 20 years profoundly affected the way teens learn, play and interact. Voluminous information is available, but the quality varies greatly. The skill of the future will not be to remember facts but to critically evaluate a vast expanse of data, to discern signal from noise, to synthesize content and to apply that synthesis to real-world problem solving. Educators should challenge the adolescent brain with these tasks, to train its plasticity on the demands of the digital age.

Greater society has some compelling opportunities as well. For one thing, it could be more focused on harnessing the passion, creativity and skills of the unique adolescent development period. Society should also realize that the teen years are a turning point for a life of peaceful citizenship, aggression or, in rare cases, radicalization. Across all cultures, adolescents are the most vulnerable to being recruited as terrorists, as well as the most likely to be influenced to become teachers and engineers. Greater understanding of the teen brain could also help judges and jurors reach decisions in criminal trials.

For teens themselves, the new insights of adolescent neuroscience should encourage them to challenge their brain with the kinds of skills that they want to excel at for the remainder of their lives. They have a marvelous opportunity to craft their own identity and to optimize their brain according to their choosing for a data-rich future that will be dramatically different from the present lives of their parents. **M**

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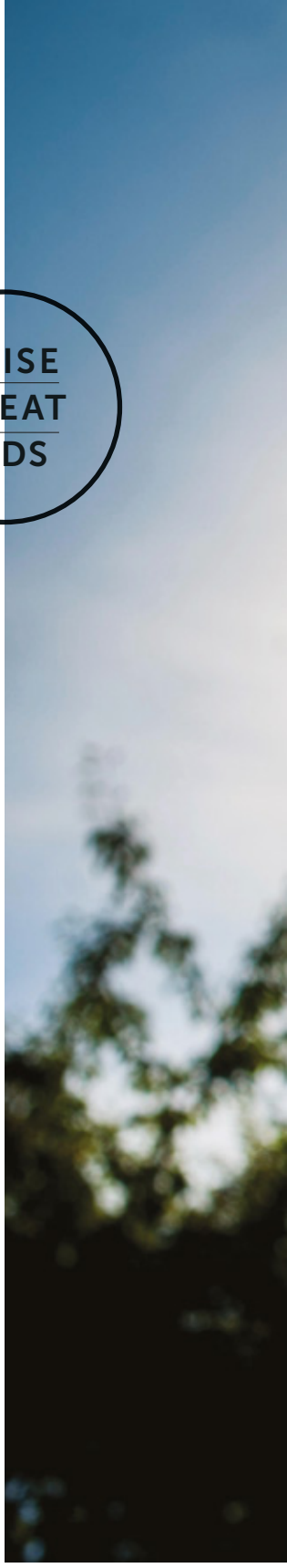
BAD MIX FOR THE TEEN BRAIN

RAISE GREAT KIDS



FAST FACTS
POISONING THOUGHTS

1. About 10 percent of eighth graders, 18 percent of 10th graders and 24 percent of high school seniors binge on alcohol; they consume a minimum of four or five drinks at a sitting at least once every two weeks.
2. High blood alcohol levels are toxic to organs, severely impair sensory and cognitive functions, and encourage habit formation or addiction.
3. Recent findings show that heavy alcohol consumption can also damage parts of the maturing brain, producing lasting deficits in learning and memory in young people.

Mike started drinking at age 14. At his very first party, he recalls, "I probably had 10 beers." He partied for seven years while playing high school and college football, and the consequences of his drinking resemble a "Just Say No" campaign: blackouts, arrests, academic problems, emergency room visits, driving suspensions and mandatory treatment programs.

About 10 percent of eighth graders, 18 percent of 10th graders and 24 percent of high school seniors binge on alcohol. That is, they consume four drinks or more at a sitting if they are female or five or more if they are male at least once every two weeks. (For the same alcohol dose, women tend to have higher blood alcohol levels than men because of their smaller size, lower body water content and lesser ability to metabolize alcohol.) In addition, 44 percent of college students drink this much or more at least twice a month.

As Mike's case illustrates, binge drinking can lead to serious health and behavioral problems. Periodic heavy drinking is more damaging to both body and brain than small-

By
Janet Hopson

er amounts of alcohol consumed more often because extremely high blood alcohol levels are toxic to organs, severely impair sensory and cognitive functions, and encourage habit formation or addiction.

Scientists have also identified a subtler, longer-lasting effect of heavy alcohol consumption among teenagers and young adults: deficits in learning and memory. An emerging body of data indicates that alcohol damages specific regions of the maturing brain. In addition, a youthful brain has weaker controls that would stop a person from drinking too much. Scientists are finding clues in the brain that may help them identify the most vulnerable young people—in hopes of halting problem drinking before it starts. According to psychiatry researcher Reagan R. Wetherill of the University of Pennsylvania, the aim is to bolster brain development "just enough" so that young people can "inhibit their own drinking behaviors before they act."

IMPULSIVE MINDS

The teenage brain is a work in progress. In the past decade neuroscientists have revealed that the prefrontal cortex, which sits at the surface of the brain just behind the forehead, is relatively slow to reach maturity. This region is the seat of inhibitory control—the ability to stop oneself from acting impulsively—and of working memory, the mental scratch pad that enables a person to temporarily hold and manipulate information. Because the prefrontal cortex can mature years later than areas governing emotion and reward, teens explore and seek independence "before their inhibitory systems are in place," disposing them toward risky behaviors, says psychiatry researcher Susan F. Tapert of the University of California, San Diego.

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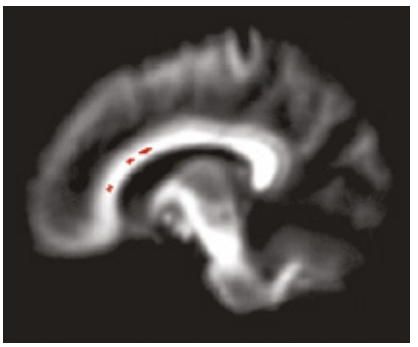
Youths whose brain maturation is slower than usual may be in particular jeopardy. In a study published in 2011 a team led by Tapert and her then graduate student Andria L. Norman, now at Wayne State University, tested the inhibitory control skills of 38 12- to 14-year-olds while they were in an MRI machine. They then tracked the youths for four years to see who would start using alcohol. The 21 kids who had begun heavy drinking had, in their original scan, shown less activation in 12 brain regions—including parts of the prefrontal cortex and the adjacent parietal cortex, which helps to produce planned movements—than the 17 who abstained. In



Heavy drinking can harm key regions of an adolescent's brain. In this image, the most prominent damage (*red spots*) appears in the bundle of nerve fibers called the corpus callosum that connects the brain's two hemispheres.

teens who went on to binge, Tapert says, "the circuitry responsible for inhibiting an action is not operating quite perfectly."

Wetherill has since tracked this diminished inhibitory capacity to a more specific brain location. In a study published in 2012 she and her colleagues used functional MRI to examine the brains of 20 12- to 14-year-olds who had never used alcohol but who came from families with alcohol problems. Teens from such families are more likely to start using and eventually abusing substances and in general tend to be more impulsive and defiant. Compared with 20 teens from families with no history of substance abuse, the brains of those in drinking families showed fewer and weaker connections between the frontal and parietal brain regions involved in planning, decision making and inhibitory control.

Studies published in 2014 and 2015 have confirmed that teens who go on to drink heavily—especially those with family histories of alcohol problems—have regions of slower brain maturation that may help identify at-risk teens before they transition into heavy drinking.

THINKING TOO HARD

Not only are teenagers susceptible to the temptation of alcohol, but evidence suggests that drinking may harm their brains. The effects of drinking on the brain are not always straightforward. Yet clear differences in brain performance distinguish teetotalers from heavy imbibers. During the past decade pharmacology researcher Fulton Crews of the University of North Carolina at Chapel Hill School of Medicine and others have shown that a high blood alcohol level in rats, a model for human binge drinking, kills cells in the brain's frontal lobes and hippocampus, a hub for memory formation. Alcohol also suppresses the birth of new neurons, among other adverse effects. Adolescent rats are more sensitive than adult ones to both these consequences—meaning the damage is greater at smaller doses. Indeed, the blackouts, and resulting amnesia, that occur in about half of all college students after binge drinking may result from hippocampal damage, says Aaron M. White of the National Institute on Alcohol Abuse and Alcoholism.

Some of the earliest insights into how drinking might affect an adolescent's learning and memory emerged in a study published in 2010 in Tapert's laboratory. Her then graduate student, Alecia Dager, now a psychiatry researcher at Yale University, tested verbal working memory—the ability to retain verbal information for short periods—in 24 nondrinking and heavy-drinking teens. Dager and her team gave the young people lists of words and word pairs to study while recording their brain activity. Later they tested the teens' recall of the words. The drinkers remembered 78 percent of the words, compared

PRECEDING PAGE: CRAIG STENNETT *Alamy*; THIS PAGE: FROM "ALTERED WHITE MATTER INTEGRITY IN ADOLESCENT BINGE DRINKERS," BY TIM MCQUEENY ET AL., IN *ALCOHOLISM: CLINICAL AND EXPERIMENTAL RESEARCH*, VOL. 33, NO. 7, JULY 2009

with 85 percent in the nondrinkers. Activity was significantly higher in parts of the prefrontal and parietal cortex of the drinkers during both learning and testing phases, probably reflecting increased effort, Dager says. In contrast, the hippocampus in the drinkers was underactive, which, in this case, the scientists interpret as echoing their poorer recall.

In 2011 a team led by Lindsay M. Squeglia, now at the Medical University of South Carolina, reported parallel findings on spatial working memory. This cognitive capacity allows you to create mental maps for, say, finding your way to a friend's house or redrawing a figure from memory. While in a brain scanner, 55 nondrinkers and 40 heavy drinkers aged 16 to 19 tried to recall shapes they had seen, among other spatial working-memory tasks. The teens who had been drinking heavily for a year or two could do the exercises as well as the abstinent youths, although their parietal cortex was much more active. Teens who had been imbibing heavily for three or four years, however, performed worse on the tasks; activity in other brain regions—those involved in vision and motor control—declined. When kids start drinking, the brain works harder to keep up, Squeglia suggests, but over time it can no longer compensate, and performance drops.

In a study published in 2012 Tapert and her colleagues similarly showed markedly higher brain activity in heavy-drinking 15- to 19-year-olds compared with nondrinkers on tasks involving visual working memory, the ability to focus on what is important in the environment. The longer a teen had been drinking, the harder the brain toiled, whereas in the nondrinkers the regions expended less energy as the teen matured.

Then Tapert's team documented in the same youths both the characteristic brain signature of low self-control and later, after they became drinkers, signs of less efficient information processing. In late 2012 the team reported scanning the brains of 40 youths twice, three years apart, starting when the kids were 15 years old, on average, while they did visual working-memory tasks. In the 20 teens who became heavy drinkers between the scans, certain parts of the frontal and parietal cortex had been initially underactive, suggesting a lack of inhibitory control. Three years later, after they started to drink, other parts of these regions showed higher activity than they did in the 20 nondrinkers, a sign that the drinkers' brains had to exert unusual effort to perform the tasks. Studies by Tapert's lab, published in 2014 and 2015, show that differences in brain structure and function predate most heavy drinking in teens, and then the drinking itself causes further changes.

If drinking escapades such as this one at Miami Beach become a habit, young people risk damaging their still developing brains.

JOE RAEDLE *Getty Images*

Collectively, the Tapert group's work suggests that the 24 percent of high school seniors and 44 percent of college students who regularly binge on alcohol might be handicapping their cognitive abilities. They score an average of 7 to 10 percent lower on verbal, visual and spatial tests than their classmates who drink very little or not at all. These young people may have more trouble reading a map, following verbal directions to a place, assembling a bookshelf, planning a project, staying organized and learning new vocabulary, among other cognitive challenges. Enough long-term data now exist on brain impairments and altered brain development, Squeglia wrote in 2015 in the *American Journal of Psychiatry,* to provide "a call for caution regarding heavy alcohol use" by teens, even before researchers have learned precisely how the damage occurs.

Someday it might be possible to "immunize" kids against the propensity to drink by bolstering their system for restraint in childhood. Wetherill is developing computer-based games and exercises that could strengthen inhibitory pathways and eventually boost self-control in the types of situations that teenagers typically face. The earlier prevention programs begin, the better. "A kid who starts drinking at 14 is four times more likely to become dependent on alcohol than a kid who starts drinking at 21," White says. Restricted teen driving permits, raising the legal drinking age to 21, and various face-to-face and Web-based interventions are making a dent in teen drinking, he adds.

No one yet knows whether the brain can fully recover from heavy drinking during its final years of development. In some of Tapert's subjects, cognitive deficits still remain after a decade. Mike eventually quit drinking, graduated from college and is now a successful account manager for a marketing company. He still experiences significant gaps, however, in his recollection of certain people and events in his past. He can only guess to what extent binge drinking and blackouts contributed because he also sustained numerous concussions playing football. The latest research, however, suggests that his partying could have contributed to a long-lasting erosion of his memory. **M**

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RAISE GREAT KIDS

WHERE'S DAD?

By
Paul Raeburn

Photoillustrations By
C.J. Burton

The influence of fathers on their teenage children has long been overlooked. Now researchers are finding surprising ways in which dads make a difference

In 2011 administrators at Frayser High School in Memphis, Tenn., came to a disturbing realization. About one in five of its female students was either pregnant or had recently given birth. City officials disputed the exact figures, but they admitted that Frayser had a problem. The president of a local nonprofit aimed at helping girls blamed the disturbing rate of teen pregnancy on television.

She pointed to the MTV shows *16 and Pregnant* and *Teen Mom*. "So much of our society is sexually oriented," she said, arguing that the fixation on sex was enticing girls to have unprotected sex earlier and more often. A lot of us might say the same thing. We know that teenagers are impressionable, and the idea that they would be swayed by MTV makes sense.

But psychologists Sarah E. Hill and Danielle J. DelPriore, both then at Texas Christian University, took note of a more subtle fact about Tennessee. Nearly one in four households was headed by a single mother. For Hill and DelPriore, that observation was a tip-off that something entirely different was going on. "Researchers have revealed a robust association between father absence—both physical and psychological—and accelerated reproductive development and sexual risk-taking in daughters," they wrote in a 2013 paper. You might expect sexual maturation to be deeply inscribed in a teenager's genes and thus not likely to be affected by something as arbitrary and unpredictable as whether or not girls live in the same house as their father. Yet the association is quite clear. The problem comes in trying to explain it. How could a change in a girl's environment—the departure of her father—influence something as central to biology as her reproductive development?

The discovery of the father is one of the most important developments in the study of children and families. Our failure to address the question of fathers' value is more than simply a matter of academic bickering.

I put that question to Hill. "When Dad is absent," she explained, "it basically provides young girls with a cue about what the future holds in terms of the mating system they are born into." When a girl's family is disrupted, and her father leaves or is not close to her, she sees her future: men don't stay for long, and her partner might not stick around either. So finding a man requires quick action. The sooner she is ready to have children, the better. She cannot consciously decide to enter puberty earlier, but her biology takes over, subconsciously. "This would help facilitate what we call, in evolutionary sciences, a faster reproductive strategy," Hill said.

In contrast, a girl who grows up in a family in which the bond between her parents is more secure and who has a father who lives in the home might well (subconsciously) adopt a slower reproductive strategy. She might conclude that she can take a bit more time to start having children. She can be more thorough in her preparation. "If you're going to have two invested parents, you're investing more reproductive resources. If the expectation is you are not going to receive these investments, you should shift toward the faster strategy," Hill explained.

THE MISSING LINK

For a long time, until women began entering the workforce in bigger numbers in the 1960s and 1970s, fathers had a uniquely valuable familial role to play. They brought home the paychecks that housed and fed their families and provided a little extra for dance lessons, Little League uniforms and bicycles for the kids. Although bringing home a paycheck might not seem like the most nurturing thing a parent could do, it was vi-

FAST FACTS
OF FATHERS AND TEENS

1. Fathers have long been neglected in research on child and family psychology, but recent work is identifying numerous ways in which they affect the development of their teenage children.
2. Among them are unexpected effects on the reproductive development of daughters and the cultivation of empathy in children of both sexes.
3. The new research suggests that a father's love and acceptance are at least as important as the love and acceptance of a mother.

tal: nothing is more devastating to the lives of children than poverty. Keeping children fed, housed and out of poverty was significant.

But was that it? What else could fathers claim to contribute to their children? The record shows that fathers have been widely overlooked in scientific studies. For example, in 2005 psychologist Vicky Phares of the University of South Florida reviewed 514 studies of clinical child and adolescent psychology from the leading psychological journals. Nearly half of them excluded fathers.

The situation has now begun to change. The discovery of the father is one of the most important developments in the study of children and families. Our failure to address the question of fathers' value is more than simply a matter of academic bickering. It is reflected in the shape of the American family. Fathers are disappearing: fewer dads are participating in the lives of their children now than at any time since the U.S. began keeping records. This shift matters because the effects of a missing father can be profound and counterintuitive—as in the age at which a daughter enters puberty.

DAUGHTERS AT RISK

Yet the links between puberty and a father's presence are just associations. They do not reveal what causes these changes. In the ideal experiment that would answer this question, we would assemble a group of families and randomly assign some of the fathers to abandon their families and others to stay. Obviously, this proposal is not likely to win approval from an ethics board. So what is the next best thing? Hill and DelPriore designed an experiment in which young women—some of them teenagers and others just past their teen years—were asked to write about an incident in which their father supported them and then were encouraged to write about a time he was not there for them. Then they were asked about their attitudes toward sexual behavior. If the researchers' hypothesis was correct, memories of unpleasant father experiences would lead the young women to express more favorable views of risky sexual behavior. Pleasant memories of their fathers should push them in the opposite direction.

And that is what happened. Women became "more sexually unrestricted" after recalling an incident in which their father was disengaged, Hill explained. Further experiments showed that father disengagement did not change women's views of other kinds of risky behavior; for instance, they were not more likely to ride a bike without a helmet. The effect was limited to sex.

Hill told me that her research rests heavily on work by Bruce J. Ellis of the University of Arizona, who helped to establish the connection between father absence and adverse outcomes for daughters. Ellis calls himself an evolutionary developmental psychologist. He wants to know whether Charles Darwin's theory of natural selection can help explain how children's environments

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shape their development—precisely the question that came up in Hill's study. His research on fathers began in 1991, with efforts to test an interesting theory. The idea was that early childhood experiences could change the way children later seek their mates. Early experience seems to "set" the reproductive strategy that girls use later in their lives. This is not true of boys, possibly because they have a different reproductive strategy.

In a series of studies beginning in 1999, he found that when girls had a warm relationship with their fathers and spent a lot of time with them in the first five to seven years of their lives, they had a reduced risk of early puberty, early initiation of sex and teen pregnancy. As Ellis continued this work, however, he became increasingly frustrated. Clearly, the association between fathers and daughters was profound. Yet he could not determine whether the parental behavior *caused* the consequences he was seeing in the daughters. An alternative explanation was that girls who begin puberty early and engage in risky sexual behavior do so because they inherited certain genes from their parents. Fathers might pass on genes linked to infidelity to their daughters, in whom they could be associated with risky sexual behavior and early puberty. Or something else in the family's environment could be responsible for the changes in their daughters.

Ellis came up with an innovative way to pose the question. He considered families in which divorced parents had two daughters separated by at least five years in age. When the parents divorced, the older sister would have had five more years with a father's consistent presence than the younger sister. If father absence causes early puberty and risky behavior, then the younger daughter should show more of that behavior than her older sibling. Also, genes or the family's environment would not confuse the results, because those would be the same for both daughters. It was close to a naturally occurring experiment, Ellis realized.

Ellis recruited families with two daughters. Some were families in which the parents divorced; others were intact, to be used as a control group. He wanted to answer two questions: Was the age at which girls had their first menstrual period affected by the length of time they spent with a father in the house? And did that age vary depending on how their fathers behaved? The second question was added because fathers with a history of violence, depression, drug abuse or incarceration can affect children's development.

Ellis's suspicions were confirmed. Younger sisters in divorced families had their first periods an average of 11 months earlier than their older sisters—but only in homes in which the men behaved badly as fathers.

"The great emphasis on mothers and mothering in America has led to an inappropriate tendency to blame mothers for children's behavior problems and maladjustment when, in fact, fathers are often more implicated than mothers in the development of problems such as these," Ronald P. Rohner says.

BUILD YOUR OWN FAMILY

Not all families have two deeply committed parents. For single parents, here are some essentials for raising kids right

By Roni Jacobson

Single-parent households are a fact of life. One in four children in the U.S. lives with only one parent, usually a single mom, according to census data. Yet a child without two committed parents need not face a disadvantage because of that fact.

Distilling a large body of research down to its essentials reveals a few key factors. The most important elements of child-rearing are not the identity or gender of the adults involved but the quality of care coming from those people, as well as its consistency over the years. In cases where one parent is absent, unreliable or uncommitted, research suggests that families keep the following priorities in mind.

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Commit

Raising a child has always been tough, but rarely does one parent manage it alone. In a study on fragile families by a group of researchers at Columbia University and Princeton University, only 17 percent of single moms reported that they were raising their children completely on their own—most of them had help from the child's father, their own parents, other relatives or friends.

Yet consistency is key. "It's not enough that there just be an adult that's on duty—one year it's the mom, the next year it's the grandma, the next year it's the biological father. You need somebody who is going to be there for the long haul," says Anne Martin, a developmental psychologist at Teachers College, Columbia University. "The child needs to feel safe and secure in his or her environment to grow intellectually and emotionally."

For older children, mentors such as teachers, coaches or religious leaders can provide support, as long as those commitments are enduring. The mentoring organization Big Brothers Big Sisters, for example, requires volunteers to commit for at least a year, with the average mentor-mentee relationship lasting two years and three months.

Collaborate

The harsh reality, though, is that the primary parent in a fractured family often struggles to find someone who can shoulder a decade or more of unflagging support. Take that study from Columbia and Princeton: most of the unmarried fathers initially said they wanted to be involved in their child's life. Yet three years after their baby's birth, almost half of the fathers living apart had not been in recent contact with their child.

One way to help engage these dads and other caregivers is to focus on their relationship with the mother. Clinical psychologist Kyle Pruett of the Yale University Child Study Center highlights this variable in his efforts to bring unengaged fathers into their children's life. "Focusing on the men alone turned out to be a waste of money and research efforts," Pruett says. "We have found that the best way to support the mother is not to deal with the father separately but to deal with him in context with her."

According to Pruett, many moms must first learn to accept that their helper will have a different parenting style than they do and not try to mold the other caregiver's behaviors to mimic her own. Duplicating efforts can even backfire, as researchers at Ohio State University found in a study published in 2011. One year after resident fathers took over parenting tasks from a mother, the couples in the study had become more combative and more inclined to undermine each other. A better strategy, the authors suggest, is for the two to decide together on their different spheres of influence, perhaps with one parent in charge of bathing and the other in control of preparing meals.

A positive relationship between caregivers can have a major impact on a child's psychological development. In a 2013 study of African-American families, researchers at the University of Vermont and the University of North Carolina at Chapel Hill found that the better the relationship between a single mother and her primary helper, the fewer mental health and behavioral problems in the children. A better bond with the primary caregiver mother can also reinforce a nonresident father's commitment to his kids. In a 2008 study led by sociologists Marcia Carlson and Lawrence Berger of the University of Wisconsin–Madison, fathers who lived apart but exhibited good communication and teamwork with their children's mom were more likely to still be involved five years after their children were born, regardless of whether the parents were romantically involved.

Engage

Women today continue to perform the majority of primary caregiving tasks, such as feeding, bathing and comforting children, even when they have a live-in spouse, although this is slowly changing. Fathers, on the other hand, tend to take part in supplementary activities, such as play, which matter less to a child's survival but assist their cognitive development. As a result, the quality of their involvement appears to matter more for children than the quantity.

In a 2013 study of fathers living apart from their biological children, for instance, scientists at the University of Connecticut and Tufts University found that neither monetary contributions nor the frequency of visits had a significant effect on the children's well-being. Rather the critical factor was how often the father engaged in child-centered activities, such as helping with homework, playing together, or attending sports events and school plays.

This kind of involvement promotes cognitive development. Known as scaffolding, such engagement helps children develop logical reasoning and problem-solving skills that translate into various situations in life. In households with two married, biological parents, both mothers and fathers tend to scaffold equally. Children living in single-parent households, however, are less likely to receive the same exposure to cognitively stimulating activities, according to a 2013 study by Carlson and Berger.

Helper parents are therefore especially important for promoting children's intellectual growth. A recent review in the *Journal of Community Psychology* found that mentors—including relatives, teachers or other involved adults—advance children's academic achievement by introducing them to new ideas and experiences and finding "teachable moments" that challenge them to think critically.

Knowledge building can happen anywhere, not only on outings to museums or in the classroom but also at dinner, while playing, or when driving to and from soccer practice. The key, researchers say, is paying attention to what children are interested in and following their lead.

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"We were surprised to get as big an effect as we did," Ellis told me. The conclusion was that growing up with emotionally or physically distant fathers in early to middle childhood could be "a key life transition" that alters sexual development.

The next step Ellis took was to look at whether these circumstances could affect the involvement of girls in risky sexual behavior. This time he turned to Craigslist and posted announcements in several cities that began, "SISTERS WANTED!" The criteria were very specific: he was looking for families with two sisters at least four years apart in age and currently between the ages of 18 and 36. He limited his search to families in which the birth parents separated or divorced when the younger sister was younger than 14 years. Ellis and his colleagues were able to recruit 101 pairs of sisters, some from families in which the parents had divorced and, using a different ad, some whose parents had not.

This time the researchers found that risky sexual behavior was not related to how long daughters lived with their fathers but to what the fathers did in the time they spent with their daughters. "Girls who grew up with a high-quality father—who spent more time as a high-investing father—showed the lowest level of risky sexual behavior," Ellis said. "Their younger sisters, who had less time with him, tended to show the highest level of risky sexual behavior."

The next question, then, is exactly how do fathers exert this effect on their daughters? One possible explanation, as unlikely as it might seem, is that a father's scent affects his daughters' behavior. Many animals emit pheromones, chemical messengers that can be picked up by others and can alter their behavior. "There is certainly evidence from animal research, in a number of species, that exposure to the pheromones of unrelated males can accelerate pubertal development and some evidence that exposure to pheromones of a father can slow it down," Ellis explained.

If the same is true of humans, pheromones could help explain how the presence or absence of fathers affects their daughters—although that remains an untested hypothesis. Some research suggests that women who sleep with a male partner have more regular menstrual cycles, perhaps because of the presence of the male's pheromones.

As we finished our conversation, Ellis brought up something I had been wondering about. What effect does father presence or absence have on sons? He told me that we do not yet know about sons. His hypothesis is that a father's involvement could have a different effect on sons, enhancing a competitive urge and spurring sons to achieve more when they grow up and leave the family.

WARTS AND ALL

As parents of teenagers understand, it is often hard to know how to respond to the crises, struggles, school challenges and social difficulties that are a normal part of the passage from childhood to adulthood. What we do *matters*—but it is so often hard to know what we should do. One key feature of good parenting, however, is to be accepting of teenagers, which again is often easier said than done—especially when they show up with a tattoo or call you from the principal's office.

Ronald P. Rohner of the University of Connecticut has spent some years looking at the consequences for children and teenagers of being either accepted or rejected by their parents. He thinks that parental acceptance influences important aspects of personality. Children who are accepted by their parents are independent and emotionally stable, have strong self-esteem and hold a positive worldview. Those who feel they were rejected show the opposite—hostility, feelings of inadequacy, instability and a negative worldview.

Rohner analyzed data from 36 studies on parental acceptance and rejection and found that they supported his theory. Both maternal and paternal acceptance were associated with these personality characteristics: a father's love and acceptance are, in this regard, at least as important as a mother's love and acceptance. That is not necessarily good news for fathers—it increases the demands on them to get this right. "The great emphasis on mothers and mothering in America has led to an inappropriate tendency to blame mothers for children's behavior problems and maladjustment when, in fact, fathers are often more implicated than mothers in the development of problems such as these," Rohner says.

Empathy is another characteristic that we hope teenagers will develop, and fathers seem to have a surprisingly important role here, too. Richard Koestner, a psychologist at McGill University, looked back at 75 men and women who had been part of a study at Yale University in the 1950s, when they were children. When Koestner and his colleagues examined all the factors in the children's lives that might have affected how empathetic they became as adults, one factor dwarfed all others—how much time their fathers spent with them. "We were amazed to find that how affectionate parents were with their children made no difference in empathy," Koestner says. "And we were astounded at how strong the father's influence was."

Although fathers matter, others can help fill that role. We all know children who grew up in difficult circumstances but now live rich and rewarding lives.

Melanie Horn Mallers, a psychologist at California State University, Fullerton, also found that sons who have fond memories of their fathers were more able to handle the day-to-day stresses of adulthood. Around the same time, a team at the University of Toronto put adults in a functional MRI scanner to assess their reactions to their parents' faces. Mothers' faces elicited more activity in several parts of the brain, including some associated with face processing. The faces of fathers, in contrast, elicited activity in the caudate, a structure associated with feelings of love.

The evidence shows that fathers make unique contributions to their children. It emphatically does *not* show that children in families without fathers in the home are doomed to failure or anything close to that. Although fathers matter, others can help fill that role [see "Build Your Own Family," on page 106]. We all know children who grew up in difficult circumstances but now live rich and rewarding lives. Not all of them grow up to be the president of the United States, but Barack Obama is an example of what can be achieved by a child who grew up without a father but managed to overcome it.

Fatherhood is about helping children become happy and healthy adults, at ease in the world, and prepared to become fathers (or mothers) themselves. We often say that doing what is best for our kids is the most important thing we do. The new attention to fathers, and the research we have discussed here, should help all of us find our way. M

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THE POSITIVE SIDE OF PEER PRESSURE

By not tapping the teenage fixation on social life, schools are missing an opportunity to motivate students

By
Annie Murphy Paul

Parents of teenagers often view their children's friends with something like suspicion. They worry that the adolescent peer group has the power to prod its members into behavior that is foolish and even dangerous. Such wariness is well founded: statistics show, for example, that a teenage driver with a same-age passenger in the car is at higher risk of a fatal crash than an adolescent driving alone or with an adult.

In a seminal 2005 study, psychologist Laurence Steinberg of Temple University and his co-author, psychologist Margo Gardner, then at Temple, divided 306 people into three age groups: young adolescents, with a mean age of 14; older adolescents, with a mean age of 19; and adults, aged 24 and older. Subjects played a computerized driving game in which the player must avoid crashing into a wall that materializes, without warning, on the roadway. Steinberg and Gardner randomly assigned some participants to play alone or with two same-age peers looking on.

Older adolescents scored about 50 percent higher on an index of risky driving when their peers were in the room—and the driving of early adolescents was fully twice as reckless when other young teens were around. In contrast, adults behaved in similar ways regardless of whether they were on their own or observed by others. "The presence of peers makes adolescents and youth, but not adults, more likely to take risks," Steinberg and Gardner concluded.

Yet in the years following the publication of this study, Steinberg began to believe that this interpretation did not capture the whole picture. As he and other researchers examined the question of *why* teens were more apt to take risks in the company of other teenagers, they came to suspect that a crowd's influence need not always be negative. Now some experts are proposing that we should take advantage of the teen brain's keen sensitivity to the presence of friends and leverage it to improve education.

NOT SO RISKY BUSINESS

In a 2011 study, Steinberg and his team turned to functional magnetic resonance imaging (fMRI) to investigate how the presence of peers affects the activity in the adolescent brain. They scanned the brains of 40 teens and adults who were playing a virtual driving game designed to test whether players would brake at a yellow light or speed through the intersection.

The brains of teenagers, but not adults, showed greater activity in two regions associated with rewards (the ventral

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NATE KITCH

striatum and the orbitofrontal cortex) when they were being observed by same-age peers than when alone. In other words, rewards are more intense for teens when they are with peers, which motivates them to pursue higher-risk experiences that might bring a big payoff (such as the thrill of just making the light before it turns red). But Steinberg suspected this tendency could also have its advantages.

In an experiment published online last August, Steinberg and his colleagues used a computerized version of a card game called the Iowa Gambling Task to investigate how the presence of peers affects the way young people gather and apply information. In this variant on the game, a computer would indicate a card from one of four decks, and players could decide to reveal that card or pass. Two of the decks would lead to an overall loss, and two would lead to overall gains. The experimenters told players that some decks were "good" and others "bad" but did not tell players which were which. Over the course of playing the game, participants gradually figured out which decks to return to and which to avoid. In Steinberg's study, which involved 101 adolescent males, researchers randomly assigned participants to play alone or in the presence of three same-age peers.

The results: teens who played the Iowa Gambling Task under the eyes of fellow adolescents engaged in more exploratory behavior, learned faster from both positive and negative outcomes, and achieved better performance on the task than those who played in solitude. "What our study suggests is that teenagers learn more quickly and more effectively when their peers are present than when they're on their own," Steinberg says. And this finding could have important implications for how we think about educating adolescents.

Matthew D. Lieberman, a social cognitive neuroscientist at the University of California, Los Angeles, and author of the 2013 book *Social: Why Our Brains Are Wired to Connect,* suspects that the human brain is especially adept at learning socially salient information. He points to a classic 2004 study in which psychologists at Dartmouth College and Harvard University used fMRI to track brain activity in 17 young men as they listened to descriptions of people while concentrating on either socially relevant cues (for example, trying to form an impression of a person based on the description) or more socially neutral information (such as noting the order of details in the description). The descriptions were the same in each condition, but people could better remember these statements when given a social motivation.

The study also found that when subjects thought about and later recalled descriptions in terms of their informational content, regions associated with factual memory, such as the medial temporal lobe, became active. But thinking about or remembering descriptions in terms of their social meaning activated the dorsomedial prefrontal cortex—part of the brain's social network—even as traditional memory regions registered low levels of activity. More recently, as he reported in a 2012 review, Lieberman has discovered that this region may be part of a distinct network involved in socially motivated learning and memory. Such findings, he says, suggest that "this network can be called on to process and store the kind of information taught in school—potentially giving students access to a range of untapped mental powers."

THE SOCIAL ADVANTAGE

If humans are generally geared to recall details about one another, this pattern is probably even more powerful among teenagers who are hyperattentive to social minutiae: who is in, who is out, who likes whom, who is mad at whom. Their penchant for social drama is not—or not *only*—a way of distracting themselves from their schoolwork or of driving adults crazy. It is actually a neurological sensitivity, initiated by hormonal changes. Evolutionarily speaking, people in this age group are at a stage in which they can prepare to find a mate and start their own family while separating from parents and striking out on their own. To do this successfully, their brain prompts them to think and even obsess about others.

Yet our schools focus primarily on students as individual entities. What would happen if educators instead took advantage of the fact that teens are powerfully compelled to think in social terms? In *Social,* Lieberman lays out a number of ways to do so. History and English could be presented through the lens of the psychological drives of the people involved. One could therefore present Napoleon in terms of his desire to impress or Churchill in terms of his lonely melancholy. Less inherently interpersonal subjects, such as math, could acquire a social aspect through team problem solving and peer tutoring. Research shows that when we absorb information in order to teach it to someone else, we learn it more accurately and deeply, perhaps in part because we are engaging our social cognition.

And although anxious parents may not welcome the notion, educators could turn adolescent recklessness to academic ends. "Risk taking in an educational context is a vital skill that enables progress and creativity," wrote Sarah-Jayne Blakemore, a cognitive neuroscientist at University College London, in a 2014 review. Yet, she noted, many young people are especially risk averse at school—afraid that one low test score or mediocre grade could cost them a spot at a selective university. We should assure such students that risk, and even peer pressure, can be a good thing—as long as it happens in the classroom and not the car. M

MORE TO EXPLORE

- **Education and the Social Brain.** Matthew D. Lieberman in *Trends in Neuroscience and Education,* Vol. 1, No. 1, pages 3–9; December 2012.
- **The Teenage Brain: Peer Influences on Adolescent Decision Making.** Dustin Albert, Jason Chein and Laurence Steinberg in *Current Directions in Psychological Science,* Vol. 22, No. 2, pages 114–120; April 2013.
- **Is Adolescence a Sensitive Period for Sociocultural Processing?** Sarah-Jayne Blakemore and Kathryn L. Mills in *Annual Review of Psychology,* Vol. 65, pages 187–287; January 2014.

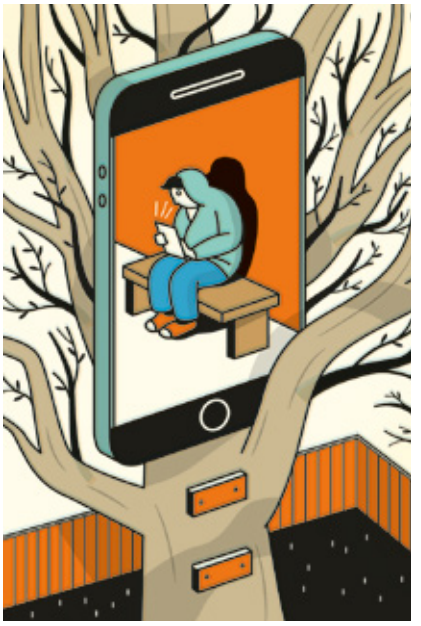
END NOTE

THE TOUCH SCREEN GENERATION

Are mobile devices ruining today's children? Science weighs in

By

David Pogue



You've met the cluck-cluckers—the people who automatically decry every new technology. "All this newfangled gadgetry is rotting our brains," they say, "and ruining our kids."

Every older generation disapproves of the next; that's predictable and human. Apparently digital devices are ruining our youth, just the way that rock music ruined their parents, and television ruined their parents and motorcars ruined theirs. So I guess we've been ruined for generations.

But I got to wondering: What does science say about the ruinous effects of the latest technology?

Part of the answer depends on your definition of "ruining." True, things are different now. Most American kids no longer "go outside and play," unattended, for hours (the stickball industry may never recover). Students no longer need to memorize the presidents and the periodic table, because Google is just a keystroke away. We are also losing old skills. Few kids know how to use carbon paper or tend horses; handwriting and driving skills may be next.

Still, different is not the same as worse. And, as I discovered, it's surprisingly difficult to find studies linking modern gadgets (touch screen tablets and smartphones) to the ruination of youth. Research takes time, and the touch screen era is very young. Nobody had ever even seen an iPad, for example, until 2010.

There is, however, early research out—and it provides some insight into how these suddenly ubiquitous gadgets might be affecting kids. One study, published in the February 2015 issue of *Pediatrics,* found that children who sleep near a small screen get an average of 21 fewer minutes of sleep than kids without gadgets in their rooms. (As for the reason: the researchers suppose that kids are staying up late to use their gadgets, or maybe light from the screen produces "delays in circadian rhythm.")

What about social skills? A 2014 study at the University of California, Los Angeles, examined 51 sixth graders who spent five days at a nature camp without electronics and 54 who did not. Afterward, the first group did better at reading human emotions in photographs.

Then there was a 2009 Stanford University study, which linked the modern teenager's multitasking computer habits (which would seem to carry over to phones and tablets) with the loss of the ability to focus. That one's a little scary.

What about brain cancer from cell phones? Surely it's bad for these kids to have a radio antenna plastered to their head all day! Well, first of all, if you know any kids, you don't need a study to tell you that they very rarely do put their phone to their head; they would far rather text than make phone calls. And anyway, studies haven't found any link between cellphone use and cancer.

Time to start cluck-clucking? Not necessarily; not all the studies draw distressing conclusions. In 2012 the nonprofit tech review group Common Sense Media found that more than half of American teens feel that social media—now accessibly anywhere thanks to touch screens—has helped their friendships (only 4 percent report that it has hurt). In 2014 the U.K.'s National Literacy Trust found that poor children with touch screen devices at home are twice as likely to read every day. Also, a study published in *Computers in Human Behavior* found that texting is beneficial for the emotional well-being of teenagers—especially introverts.

Clearly, we still need broader, longer-term studies before we begin a new round of cluck-clucking. And they are coming; for example, results of a huge British survey of 2,500 children called SCAMP (*S*tudy of Cognition, *A*dolescents and *M*obile *P*hones) will arrive in 2017.

In the meantime, the warning bells raised by early research are not loud enough to make us rip our kids' touch screens away and move to Amish country. Yet they are already enough to suggest practicing a very wise, ancient precaution: moderation. Too much of anything is bad for children—whether it is modern electronics, watching TV or playing stickball. M

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