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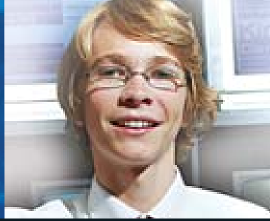

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Growing Brains

I knew I was being watched. Dark eyes tracked my movements, intent. Impulsively, I grinned widely. I picked up a stuffed elephant from the menagerie on the coverlet and hugged and kissed it. Her eyes widened slightly as my baby daughter registered the idea. Today she is six years old, and "Ellie" is still her favorite plush companion when she needs a cuddle and mommy is not immediately available.

As the articles in this special issue underscore, a child's rapid cognitive development begins from the earliest ages and may continue into young adulthood. Before they can talk, tots are learning how the world works and how they can apply that knowledge. "Test Subjects in Diapers," by Gisa Aschersleben, reveals how quickly infants learn to think critically—and the ways in which scientists can "ask" babbling babies to show what they know; turn to page 10.

Knowledge about a child's rapid mental development also serves to emphasize the importance of early intervention in cases where children have special needs. Articles in the issue explore faster detection of disorders and possible therapies for children with autism (page 14), ADHD (page 36) and Down syndrome (page 42).

When does the brain finish "growing up"? Many neuroscientists say that cognitive development, especially in areas of the brain that are associated with decision making and other "executive" functions, continues into the second decade of life, reports Leslie Sabbagh in "The Teen Brain, Hard at Work," beginning on page 54. Meanwhile psychologist Robert Epstein warns against excess reductionism in applying imaging studies of teen and adult brains to complex human behaviors. We blame teen turmoil on immature brains—but, he asks, did the brains cause the turmoil, or did the turmoil affect the brains? His article, "The Myth of the Teen Brain," starts on page 68.

As you page through the articles in the issue, we hope one thing will be clear: as we learn more about how the mind operates, we are better able to help children grow up to lead happy, fulfilling lives.

Mariette DiChristina
Executive Editor
editors@sciam.com

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TEENAGE YEARS

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

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Big Answers from Little People

In infants, **Elizabeth Spelke** finds fundamental insights into how men and women think

By David Dobbs

If you had been blind all your life and could suddenly see, could you distinguish by sight what you knew already by touch—say, a cube from a sphere? Would flowers look like flowers you'd felt and faces like faces, or would they all be confusing patterns? How would you start to make sense of the many objects in your immediate view? If we are born knowing nothing, how do we come to know anything?

Harvard University psychologist Elizabeth Spelke takes these questions to the people who may be best able to answer them: babies. Spelke, whose sprawling laboratory in William James Hall teems with infants and researchers who are interested in them, has addressed some of the most intractable mysteries of human knowledge by interrogating little people who cannot yet talk, walk or even crawl. She has what she calls "an insatiable appetite" for assessing these young beings. Through Web pages, flyers and letters to day care centers and pediatricians' offices, her lab mates ask anyone and everyone for diminutive volunteers. They watch as the little subjects sit on their mothers' laps, tracking the stagecraft that Spelke and her cohorts use to gauge early understanding of numbers, language, objects, space and movement.

Spelke's findings have helped revise sharply our notion of what humans can make sense of in their first days, weeks and months. In doing so, she has offered some of the most substantial evidence to date regarding nature versus nurture. Spelke's discoveries about infant capabilities have become central to ongoing attempts to figure out human cognition.

From her insights she has forged a bold, if still controversial, theory of "core knowledge," which asserts that all humans are born with basic cognitive skills that let them make sense of the world. This core knowledge, she says, underlies everything we learn throughout our lives and both unifies and distinguishes us as a species. Her theory prompted the American Psychological Association to honor her with its William James Fellow Award in 2000. And her work shows that, despite people's differences, we all have more in common than we recognize.

(Spelke has shown that **humans of all races** and both sexes are born with similar "core knowledge.")

Clarity, Not Confusion

The heart of Spelke's methodology is her observation of "preferential looking"—the tendency of infants and children to peer longer at something that is new, surprising or different. Show a baby a toy bunny again and again, and the baby will give it a shorter gaze each time. But give the bunny four ears on, say, its tenth appearance, and if the baby looks longer, you know the baby can discern four from two. The approach neatly bypasses infants' deficiencies in speech or directed movement and makes the most of the one thing they control well: how much time they fix their eyes on an object.

Spelke did not invent the scheme of studying preferential looking. That credit falls to Robert L. Fantz, a Western Reserve University psychologist who in the 1950s and early 1960s discovered that chimps and infants stare longer at things they perceive as unexpected. A researcher could gauge an infant's discriminatory and perceptual powers by showing the baby different, highly controlled scenarios, usually within a stagelike box, and observing what changes in the scenarios the infant would perceive as novel.

Using this basic technique, Fantz and others soon found that the infant's world was not, as pioneering psychologist William James had opined in 1890, a "blooming, buzzing confusion." Infants made sense of the world readily. For example, Fantz and others found that newborns could differentiate red from green, two-month-olds could discriminate all primary colors, and three-month-olds preferred yellow and red to blue and green. They found that a newborn could distinguish between her mother's face and a stranger's (unless both adults wore scarves over their hair), a four-month-old could recognize acquaintances, and a six-month-old could interpret facial expressions. By the 1970s psychologists recognized the first year of life as a far more explosive developmental period than they had ever considered it to be.

This work attracted Spelke when she was still an undergraduate at Radcliffe College. From 1967 to 1971, she studied with Harvard child developmental psychologist Jerome Kagan and quickly found herself hooked on the excitement of investigating the essential workings of human cognition by analyzing children. She continued that research while pursuing her Ph.D. in psychology at Cornell University, where famed developmental psychologist Eleanor J. Gibson served as her graduate adviser and mentor. Gibson, one of only a handful of psychologists to win the National Medal of Science, had revealed much about infant cognition with some elegant

ROSE LINCOLN *Harvard News Office (preceding pages)*

Researchers gauge an infant's perceptual, attentional and discriminatory powers by manipulating objects in highly controlled scenarios and recording what the baby focuses on (*left*) and which changes he or she perceives as novel (*right*).

KATHARINA CIEPLAK-VON BALDEGG

experiments of her own. Her best known was the "visual cliff," a piece of heavy glass extending from a tabletop. Would early crawlers avoid the apparent drop-off? Most do, a discovery that revised theories of infants' spatial understanding.

Under such tutelage, Spelke hit on her own landmark experiment. "At dinner one night," she recalls as we talk in her office at Harvard, "I was musing with a fellow student over whether, when babies look at and listen to something, do they perceive [the sight and sound of an event] as two separate things, or do they recognize a link between the two? How would you find that out? Suddenly, I had this image of two visual events going on side by side, like movies, and between them a loudspeaker that you could switch from the sound of one event to the sound of the other event. Would a baby turn to look at the event matching the soundtrack the speaker was playing? That experiment became my Ph.D. thesis. It was the first time I was able to start with a general question about how we organize a unitary world from multiple modalities and turn the question into a ridiculously simple preferential-looking experiment—which actually ended up working."

Sure enough, Spelke found that babies recognized the link between sound and sight, switching their gaze back and forth as the soundtrack changed. Thus began Spelke's career of pondering big questions with straightforward experiments on tiny people. The mixed-modality approach addressed the same "binding problem" faced by blind people who suddenly can see: How does the brain mesh the signals from different senses into a single impression? Spelke did not answer how, but she did show persuasively that this ability seems innate.

Native Knowledge

Over the years Spelke has conjured up many other elegant and productive investigations on object and facial recognition, motion, spatial navigation, and numerosity (grasping of numerical relationships). She is able to envision simple but powerful tests, she says, "because I think like a three-year-old." By showing babies objects in motion and then interrupting their logical speed or course, she has found that even a four-month-old infers that a moving object is supposed to keep moving. Yet it takes an eight-month-old to grasp the principle of inertia and expect the object's path to be consistent and smooth. By showing babies different arrays of disks, she has found that six-month-olds can distinguish eight from 16 and 16 from 32—but not eight from 12 or 16 from 24. By having babies watch a person reach for one of two objects on a table, she has found that although 12-month-olds know from an adult's gaze which object he will grab, eight-month-olds do not.

As the data from such clever designs mounted, Spelke began to develop her theory of core knowl-

(The Author)

DAVID DOBBS is a freelance science and medical writer who lives in Montpelier, Vt. He is author of *Reef Madness: Charles Darwin, Alexander Agassiz, and the Meaning of Coral* (Pantheon Books, 2005). His writing can be found at www.daviddobbs.net

“The rich **core knowledge** we share gives us common ground,” Spelke says, “something we badly need.”

edge, often inspired by or collaborating with colleagues such as noted Massachusetts Institute of Technology linguist Noam Chomsky, French mathematician turned cognitive neuropsychologist Stanislaus Dehaene and Harvard psychologist Susan Carey. Core knowledge systems, Spelke says, are neuronal “modules” that are in place at birth for building mental representations of objects, persons, spatial relationships and numerosity. Somewhat akin to the “deep grammar” that Chomsky believes underlies all human language, these core knowledge modules enable all infants to organize their perceptions.

The sophistication of these systems in infants resembles that of modules in nonhuman primates, suggesting an ancient, evolutionary development; a six-month-old baby understands numbers, space, objects and faces much as a mature rhesus monkey does. As Spelke sees it, these cognitive tools underlie all the more complex skills and knowledge we master as we grow up—spoken languages, number manipulation and other abstract mental operations. Core knowledge forms the basis for the robust cognitive machinery that gets us through life. And we almost completely ignore it.

“Even for adults,” Spelke says, “most of what we know that lets us negotiate the world, guide our choice of paths through the environment, understand whether a car down the street might hit us or whether a falling object will miss us, even what we say as we’re conversing—most of that is completely unconscious. How many things do we do that we hardly think about? Most of what we do is like that. We operate on richly structured cognitive systems that aren’t usually accessible to introspection. To me, this is one more sign that most of our cognitive workings are much like those of babies and are built on the core knowledge that we had as babies.”

Spelke was plunged into controversy in 2005 when Harvard University president Lawrence Summers (*opposite page*) remarked that biology might explain why women occupy so few college math and science jobs. The foundations for these disciplines, she said publicly, “develop equally in males and females.”

KIRSTEN CONDRY

Equality of the Sexes

This view of Spelke’s is what philosophers call a “nativist” theory—that certain of our traits are inborn. They are natural rather than nurtured. Spelke knows well that this puts her on a slippery slope. To speak of native abilities is to court speculation about native differences in those abilities. In early 2005 Spelke found herself involved in a hot controversy about such possible differences when she was repeatedly asked for her opinion of Harvard president Lawrence Summers’s remarks, made that January, that biological disparities might help explain why women occupy so few places in university math and science departments. Spelke, of course, was the natural choice to debate this topic, not only because she was a prominent, highly accomplished scientist at Summers’s university but because she got there by studying precisely the innate abilities Summers wondered about. Although she hardly seems a scrapper by inclination, Spelke is quick-witted, funny, impressively well informed and eminently agile in conversation. And she rose quite gracefully to the task of popping Summers’s thought balloon.

“If you look at things Summers’s way,” she says in her office, leaning forward in her chair with a sly grin, “then to study innate cognitive abilities, like I do, is supposedly to study gender differences. In fact, I didn’t know we were studying gender differences at all, because we don’t find any. But since the subject came up”—she spread her hands, clasped them, then sat back in her chair, smiling—“I was happy to tell him about our work.”

After controversial remarks in 2005 about women's abilities in math and science, Summers (*center*) eventually stepped down the next year.

STEVEN SENNE *AP Photo*

Summers got an earful, if not directly, as Spelke described in several interviews and in a high-profile public debate with her colleague and friend Harvard psychologist Steven Pinker how voluminous evidence from decades of research shows little if any inherently sex-based differences in infants or toddlers. At those early ages, when culture has the least effect but sex hormone levels are extremely high, no sex-based differences have shown themselves in a huge variety of skills that underlie mathematical thinking. For example: put a four-year-old in a distinctly shaped room, hide a block in a corner, have the four-year-old close his eyes and spin around, then have the child hunt for the block. Some of the children will quickly reorient themselves in the room and find the object, whereas others will not. Yet the percentages of boys and girls who succeed are identical. So although "there is a biological foundation to mathematical and scientific reasoning," as Spelke put it in her debate with Pinker, "these systems develop equally in males and females."

Spelke, an unabashed optimist, believes our growing understanding of cognitive abilities will eventually reduce, rather than inspire, divisions about our human qualities. "This idea that we have native abilities," she tells me, "some find threatening, for it seems to invite the idea that some types of people might be innately better endowed than others. If you're a nativist about basic core cognitive capacities, as I am, does that also lead you to be a nativist about, say, differences among the sexes? These claims of biological bases can proliferate to a point where they end up being invoked to explain everything. But you have to be very careful about what data you use." The information that seems to indicate sex differences, Spelke says, comes from problematic studies whose results are colored by cultural influences—everything from parents responding differently to girls and boys to university faculties viewing identical job applications more skeptically when the applicant's name is female. Summers must have taken that last point to heart: in May 2005 he announced that Harvard would spend $50 million over 10 years to recruit and support women and minorities on its faculty.

Meanwhile the expanding pile of data on infants, who are not tainted by culture, shows remarkable parity among sexes and races. "We're getting evidence for an intricate and rich system of core knowledge that everyone shares and that gives us common ground," Spelke declares. "In a world of so much conflict, I think that's something we badly need." M

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Test Subjects in Diapers

By Gisa Aschersleben

Toby lies in his crib watching his mother, Claudia, as she does housework. He babbles happily and kicks his legs with delight as one piece of clothing after another disappears into the washing machine. "I wonder if he realizes that I am intentionally picking up this T-shirt to put it into the machine?" Claudia asks. "And does he consciously control his movements?"

Parents aren't the only ones who wonder. Researchers have been asking similar questions in studies during the past two decades. In recent years, they have gained some surprising insights into the cognitive development of infants. As it turns out, even the smallest babies know far more than we have traditionally given them credit for.

For centuries, infants were viewed as virtually passive beings who absorbed little information from their environment and whose movements were almost exclusively reflexive. The situation is very different today: scientists know that a human being learns at an astonishing rate during the first few months after birth, perhaps faster than at any other time in his or her life. Babies explore the world with all senses, and their brains process an abundance of experiences and stimuli. Psychologists are probing exactly when the seeds of reasoning begin to sprout.

Little Test Subjects

How does one study the capabilities of children who cannot yet talk? Psychologists turn to an array of testing techniques based on the systematic observation of baby behavior. First, the procedures take advantage of an infant's natural attentiveness to new objects or situations. The more surprising the situation, the longer the infant focuses. Babies also find dolls, plush animals, unusual sounds and light effects appealing. Second, infants are very imitative, providing another way to delve into their development. Tests do, nonetheless, have to take a youngster's physical progress into account. For instance, tasks that involve grasping and shaking an object are not suitable for a child younger than about six months.

One of the major questions about babies' capabilities that researchers have explored is, Do

FAST FACTS
The Onset of Reasoning

1» Psychologists across the globe are studying the development of analytical reasoning in infants during the earliest months of life.

2» Far from being passive observers, babies as young as six months can understand the intentions of others and begin to be able to foresee the outcomes of their own actions.

When do babies recognize the intentions of others—and become capable of deliberate actions themselves?

babies learn from watching the actions of others? For example, suppose a child watches an adult manipulating a puppet that is wearing a glove. The adult removes the puppet's glove and shakes it three times, causing a bell to ring, and then puts the glove back on. After demonstrating this sequence several times, the adult gives the puppet to the baby. While the baby plays with the puppet, researchers analyze their little subject. Surprisingly, children as young as six months make use of their previous observation. They repeat the first step of the action sequence they have observed—taking off the glove—far more often than do members of a control group, who did not see the sequence. Over a 24-hour period, they continue to remember the action, as long as the opportunity to play with the puppet is repeated often enough. Children are not able to master all three steps, however, until they are about 15 to 18 months old.

Does he understand the purpose behind your actions? Probably yes.

DIGITAL VISION/GETTY IMAGES

To study the capabilities of children who cannot yet talk, psychologists turn to observations of behavior.

An eight-month-old can recognize someone else's intention and act on it. If an adult leaves a toy car out of reach, for instance, the baby will pull an attached string to get it.

Another research question is, Do infants merely copy the movements of others, or can they imagine an effect that they then set out to produce? "Conditioning" experiments, popular in the 1960s, established that even newborns can learn to elicit pleasurable effects by making particular movements—that is to say, they can be conditioned at a very early age. They move about and take in and process interesting phenomena in their surroundings almost as soon as they are born. From their experiences they then discover contingency, the relation between their own movements and events that occur in the environment around them. In experiments with nursing newborns, they can learn to suckle at a certain frequency to elicit through a headset the soothing voice of their own mother but not that of another woman. Another way we have studied infants' familiarity with contingency in the lab is with mobiles. The baby lies in a crib, with a string fastened to her ankle and to a mobile. Whenever she kicks, she sees the mobile move. Within a few minutes she discovers this contingency, and she kicks more frequently.

Experiments based on imitation, rather than on conditioning, also can be revealing. In 2002 my research group at the Max Planck Institute for Human Cognitive and Brain Sciences in Munich conducted a study in which 72 12- and 18-month-olds watched a man perform a three-part series of actions. The adult picked up a cylindrical wooden block that had been placed in front of a teddy bear, shook it and then returned it to its original position. For one group of children, shaking the block made an interesting buzzing sound; for another group, putting it back caused the sound.

After the demonstration, children played with the bear and the block. They imitated the action that caused the sound both more often and earlier than did children in a control group, where no demonstration had been made. From this study, we learned that at the age of one year (and perhaps earlier) children use the knowledge gained from observation to anticipate the effects of their actions.

In another experiment, we wanted to determine the age at which babies recognize that the effects they themselves initiate are not identical to the effects they have observed previously. This time, when a tester pulled on a red plastic ring, a clear tone sounded; pushing on the ring caused it to light up. Subsequently, before letting children play freely with the object, experimenters reversed the order: pulling led to the light, whereas pushing created the sound. Children from about the age of 15 months noticed this difference; only at that age did they perform the observed movement with the ring less often than did children in a control group, for whom the order was not reversed. This outcome means that only during year two do children begin to recognize the particular relation between someone else's action and its effect and those of their own.

Intentional or Inadvertent?

Further experiments suggest that babies only five or six months old can recognize the actions of others as intentional. Amanda L. Woodward, now at the University of Maryland, conducted just such a study in 1998. Infants watched a hand on a stage repeatedly grasp a particular object, such as a tower, but not a second object that had been placed right next to it, such as a cube. The positions of the tower and cube were then switched. In one variation of the test, the hand again reached

(The Author)

GISA ASCHERSLEBEN is a professor of developmental psychology at Saarland University in Saarbruecken, Germany.

COURTESY OF GISA ASCHERSLEBEN

By about a year old, children can anticipate the effects of their actions. If a child has seen that shaking a cylindrical wooden block causes an interesting sound, he will shake the block much more frequently.

Even during their first year, children probably **understand more** about your actions than you realize.

for the tower but used a different motion to grab it because of the switched position. In a second version, the same motion was made, but the hand picked up the cube. The tots found this latter maneuver much more fascinating: they watched considerably longer when the target object of the action changed but the hand movement remained the same. This observation demonstrates that children between five and six months can interpret as intentional the grasping movements of others.

What if the actions are new and unfamiliar? Seeking an answer, our research group extended Woodward's experiment. We presented the babies with a hand, the back of which touched a tower and pushed it to a new position. We found that babies as young as six months can realize that this unfamiliar action is intentional—but only if the actions are accompanied by a clearly recognizable effect, such as a change in the tower's position. If this effect is omitted, babies treat the action as inadvertent. Another Woodward study, reported in 2005 in the journal *Cognition,* found that by the age of one year, babies can even recognize that separate actions made by another person are governed by an underlying plan.

Thus, the traditional perspective—that understanding the behaviors of others is predicated on one's own prior actions—has been called into question by the latest research conducted by developmental psychologists. It may be that these capacities develop in parallel. Even if Toby is as yet unable to carry out particular movements purposefully, he certainly can comprehend his mother's intentions. This aspect of baby development is similar to speech, where the ability to understand comes well before that of speaking.

The upshot for parents is: even during their first year of life, your children probably understand a good deal more about your actions than you realize. **M**

COURTESY OF GISA ASCHERSLEBEN

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Detecting Autism Early

New techniques could diagnose autism in babies, enabling more effective treatment while the brain is most malleable By Ulrich Kraft

Anyone who has spent even a little time with an autistic boy or girl soon becomes familiar with the behaviors that set these children apart: lack of eye contact, trouble verbalizing, overreacting or underreacting to activities around them, difficulty in expressing their feelings and in understanding the emotions of others. But how do parents and doctors know if a baby, who is too immature to be gauged on any of these traits, has autism? Early diagnosis has proved difficult.

Inability to detect autism until a child is two or three years old is a terrific disadvantage. It "eliminates a valuable window of treatment opportunity, when the brain is undergoing tremendous development," says David G. Amaral, professor of neurobiology and psychiatry at the University of California, Davis.

Amaral and researchers at other institutions, however, are closing in on techniques that could detect autism in babies as young as six months and perhaps even at birth. The results of these new tests—some controversial—are expanding the understanding of autism and raising hopes for much earlier, specialized care that could improve a toddler's chances for a more normal life as a child, teenager and adult.

BERNARD BISSON *Sygma/Corbis*

Tests showed that autistic children had different levels of immune cells and proteins in their blood.

Gwendoline, age 6, is comforted by her mother. Some children may not be doomed at birth; something in their infant environment might trigger a genetic predisposition.

BERNARD BISSON *Sygma/Corbis*

A Simple Blood Test?

Autism affects a wide variety of developmental traits. Some young autistic children speak; others do not. Some possess almost average intellectual abilities; others are severely limited. As they grow older, certain autistic individuals display incredible talents in very specific domains. Known as savants, they can memorize an entire book in hours or solve complex math problems faster than people using a calculator. The 1988 movie *Rain Man* dramatized these abilities in a character named Raymond Babbitt, played by Dustin Hoffman, who won an Oscar for the role. Babbitt was based on a real savant named Kim Peek, who continues to astonish today.

It is no wonder, then, that determining whether a young child is autistic is fraught with uncertainty. Diagnosis typically involves rating a child's behaviors against a set of standards. The exercise usually is not conclusive until at least the child's second birthday. That is why scientists are seeking an earlier and more accurate test, and they are getting closer. At the International Meeting for Autism Research in Boston in May 2005, Amaral presented the initial results of a landmark study. His team compared blood samples from 70 autistic children ages four to six with samples from 35 randomly selected subjects in the same age group. The autistic children had a higher proportion of two basic immune system cells known as B cells and T cells. Significant differences also became apparent in more than 100 proteins and small molecules commonly found in the bloodstream.

After further analysis, the team decided that the pilot study results were strong enough to launch a full-scale investigation. In March 2006 Amaral announced that U.C. Davis's Medical Investigation of Neurodevelopmental Disorders Institute, which he heads, was starting the Autism Phenome Project. It will enroll 900 children with autism plus 450 more who have developmental delays and 450 who are developing normally. Researchers will analyze the children's blood proteins, immune systems, brain structures and functions, genetics and environmental exposures. The participants will be two to four years old at the outset and will be followed for several years. Amaral thinks it is probable that telltale genetic markers will be found. But it will take several years before the project is finished and analyzed and longer still before a routine test for autism could be administered at a doctor's office.

If the blood profiles prove to be reliable, the screening could occur just after a baby is born.

But the validity of detection that early in life requires more scrutiny. Amaral says there is a growing view among experts that not all individuals who have autism are "doomed at birth," as has been commonly believed. "It may be that some children have a vulnerability, such as a genetic abnormality," he says, "and that something they encounter after being born, perhaps in their environment, triggers the disorder."

Environment is suspected in part because the incidence of autism is fairly high in American children. The disorder affects one in every 150 eight-year-olds, according to the latest estimates from the U.S. Centers for Disease Control and Prevention. The unexplained preponderance has frustrated scientists trying to find answers. Furthermore, tremendous variation exists among symptoms, "which leads us to believe that autism is a group of disorders rather than a single disorder—several autisms versus one," Amaral says. The blood work could possibly define distinct subtypes. Behavioral experts are reaching the same conclusion, many preferring the term "autism spectrum disorder" rather than simply "autism."

Earlier Treatment Is Key

An early diagnosis is so important because it would allow treatment to begin sooner, while the brain is still significantly strengthening and pruning neural networks. A paradigm shift is taking place on this issue, too. For a long time, scientists believed that functional deficits in certain brain regions caused autism—complications in brain structure that no change in wiring among neural networks would fix. Now they think symptoms arise because of communications problems between brain regions—problems that rewiring could solve if babies received specific therapy.

"The neuronal networks apparently do not coordinate very well," explains Fritz Poustka, director of child and adolescent psychiatry at Goethe University in Frankfurt, Germany. Poustka says regions that get too little input from other parts of the brain do not develop well. This effect is well known among children who were neglected when they were young, some isolated from almost all human contact. A child who develops this way shares some similar consequences, such as poor use of language and difficulty in making social connections. "A quick diagnosis of autism would enable us to stimulate the networks very early in life by deliberately providing the right inputs," Poustka says. He cannot say if such interventions would "cure" the disorder, but he believes that intensive behavioral training could make the symptoms milder.

Although Poustka doubts that markers in the blood would permit early diagnosis, he favors attempts to try to define telltale traits as young as possible to maximize the success of treatment. In speech development, for example, the best results are achieved when deliberate exercises are instituted before the child's second birthday. By the time a boy or girl is three or four, deficits can still be reduced, but fundamental changes are no longer possible, because the critical period during which speech develops has passed by.

Behaviors Untangled

Whether or not Amaral's project leads to common blood tests, it could prove beneficial to behavioral approaches as well because it includes developmentally delayed children. The standardized checklists that doctors now use for diagnosis, such as the "autism diagnostic observation schedule," are adequate only for children who are at least one and a half to two and a half years old. And then, usually only for the so-called high functionals—autistic children with IQs over 80.

Certain situations are difficult for autistic children to understand. If they could be diagnosed as babies, earlier behavioral training could make symptoms milder.

BERNARD BISSON *Sygma/Corbis*

(The Author)

ULRICH KRAFT is a contributor to *Gehirn & Geist.* He wrote about disorders of the brain's timekeeping mechanism in the June/July 2007 issue of *Scientific American Mind.*

Common Behaviors

The traits most characteristic of autistic people are aloneness, an insistence on sameness and a liking for elaborate routines. At the same time, some autistic individuals can perform complicated tasks, provided that the activity does not require them to judge what some other person might be thinking. These traits lead to characteristic forms of behavior, a number of which are portrayed here.
—Uta Frith, University College London

Displays indifference

Is one-sided in interactions

Indicates needs by using an adult's hand

Talks incessantly about one topic

Parrots words

Joins in only if an adult assists

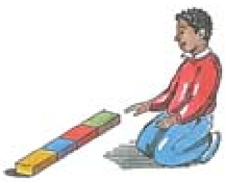
Behaves in unusual ways

Does not play well with other children

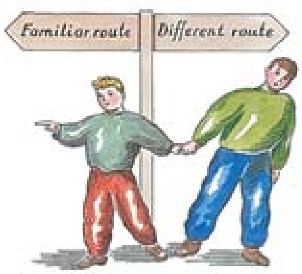
Laughs and giggles inappropriately

Handles or spins objects

Does not make eye contact



Does not pretend in playing



Prefers sameness

Yet performs certain tasks well if they do not involve social understanding

RODICA PRATO

The tests are inconclusive for many of the other suspected individuals because children who are delayed in their intellectual development often score similarly to children who truly have autism. It is difficult to determine whether cognitive problems are being misdiagnosed as symptoms of autism, Poustka says. Delay, or a completely different disorder, can prompt what appear to be autismlike patterns.

A Canadian research team is trying to clarify this overlap. Led by Lonnie Zwaigenbaum, now at the University of Alberta in Edmonton, the group devised a 16-point observational checklist called the Autism Observation Scale for Infants and used it to evaluate 65 one-year-old children, all of whom had older siblings with autism and therefore had an above-average chance of developing the disorder themselves. The researchers also assessed another 23 babies with no familial ties to or signs of autism.

Jay, 23, walks to bingo night, the one social activity he does on his own. Offering autistic toddlers a more fruitful childhood raises their chances for more satisfying years as adults.

KAT WADE *San Francisco Chronicle/Corbis*

(Children diagnosed at age two had shown seven or more telltale behaviors when they were only one.)

Zwaigenbaum's group reappraised the children when they were two, this time using traditional tests. They found that almost all the children who were diagnosed as autistic at age two had seven or more distinguishing traits when they were only one. "The predictive power of these markers is remarkable," Zwaigenbaum says.

Even among children just six months old, certain behavioral patterns forecast the onset of the disorder, notably a passive temperament and low physical activity levels. By their first birthdays, the children who later turned out to be autistic were easily irritated, had problems with visual tracking, tended to focus on a very few objects, failed to look around for a speaker who said their name, and barely interacted with others. They also tended to have certain obsessive motions, such as stroking surfaces, yet made very few gestures toward other people. And they understood less spoken language than their age-mates who were later identified as nonautistic.

As Amaral acknowledged about his first blood-profile exploration, Zwaigenbaum notes that further studies must include children who are at risk for other developmental disorders to help distinguish which symptoms are specific to autism. He is also open to the possibility of environmental influences in triggering or at least exacerbating autism. He says it is hard to know if the traits his group identified are early manifestations of the disorder or if they contribute to a pattern of development that may lead to autism.

Either way, his investigation, Amaral's and those of others are all improving our understanding of when autism starts, providing hope for earlier diagnosis and more effective treatment. The goal, of course, is to offer toddlers a greater chance at a more fruitful childhood, which in turn raises their chances for more satisfying years as teenagers and adults. The many challenges that autistic individuals face as they mature—learning, communicating with others, making and keeping friends, building life skills, securing a job, finding love—will be less daunting if they can get off to an earlier, better start. **M**

(Further Reading)

- **Behavioral Manifestations of Autism in the First Year of Life.** Lonnie Zwaigenbaum et al. in *International Journal of Developmental Neuroscience,* Vol. 23, Nos. 2–3, pages 143–152; April–May 2005.
- **Autistic Brains Out of Synch?** Ingrid Wickelgren in *Science,* Vol. 308, pages 1856–1858; June 24, 2005.

Children with autism may struggle with social interaction because their mirror neuron systems are not functioning properly.

Studies of the mirror neuron system may reveal clues to the causes of autism and help researchers develop new ways to diagnose and treat the disorder

Broken Mirrors

A Theory of Autism

By Vilayanur S. Ramachandran and Lindsay M. Oberman

At first glance you might not notice anything odd on meeting a young boy with autism. But if you try to talk to him, it will quickly become obvious that something is seriously wrong. He may not make eye contact with you; instead he may avoid your gaze and fidget, rock his body to and fro, or bang his head against the wall. More disconcerting, he may not be able to conduct anything remotely resembling a normal conversation. Even though he can experience emotions such as fear, rage and pleasure, he may lack genuine empathy for other people and be oblivious to subtle social cues that most children would pick up effortlessly.

CARY WOLINSKY (*photograph*); JEN CHRISTIANSEN (*photoillustration*)

Mirror neurons appear to be performing precisely the same functions that are disrupted in autism.

In the 1940s two physicians—American psychiatrist Leo Kanner and Austrian pediatrician Hans Asperger—independently discovered this developmental disorder, which afflicts about one in 150 American children. By an uncanny coincidence each gave the syndrome the same name: autism, which derives from the Greek word *autos,* meaning "self." The name is apt, because the most conspicuous feature of the disorder is a withdrawal from social interaction. More recently, doctors have adopted the term "autism spectrum disorder" to make it clear that the illness has many related variants that range widely in severity but share some characteristic symptoms.

Ever since autism was identified, researchers have struggled to determine what causes it. Scientists know that susceptibility to autism is inherited, although environmental risk factors also seem to play a role. Starting in the late 1990s, investigators in our laboratory at the University of California, San Diego, set out to explore whether there was a connection between autism and a newly discovered class of nerve cells in the brain called mirror neurons. Because these neurons appeared to be involved in abilities such as empathy and the perception of another individual's intentions, it seemed logical to hypothesize that a dysfunction of the mirror neuron system could result in some of the symptoms of autism. Over the past decade, several studies have provided evidence for this theory. Further investigations of mirror neurons may explain how autism arises, and in the process physicians may develop better ways to diagnose and successfully treat the disorder.

FAST FACTS

Mirror Neurons and Autism

1» Because mirror neurons appear to be involved in social interaction, dysfunctions of this neural system could explain some of the primary symptoms of autism, including isolation and absence of empathy.

2» Studies of people with autism show a lack of mirror neuron activity in several regions of the brain. Researchers speculate that treatments designed to restore this activity could alleviate some of autism's symptoms.

3» A complementary hypothesis, the salience landscape theory, could account for secondary symptoms of autism such as hypersensitivity.

Explaining the Symptoms

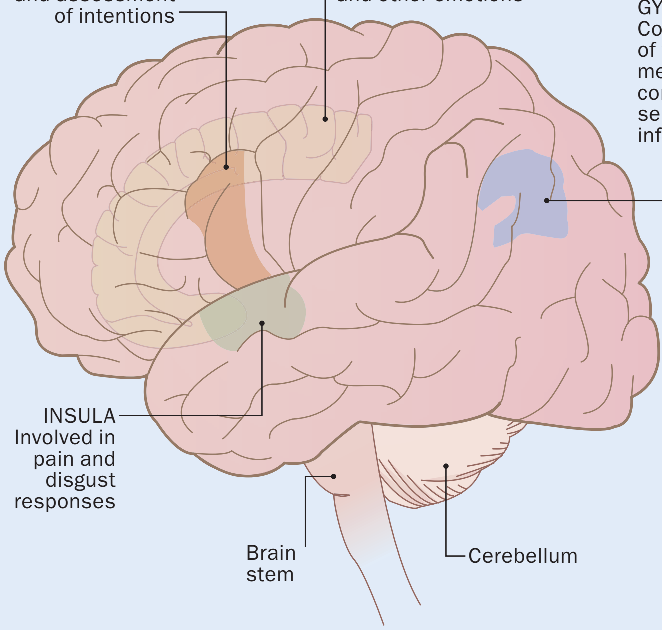
Although the chief diagnostic signs of autism are social isolation, lack of eye contact, poor language capacity and absence of empathy, other less well known symptoms are commonly evident. Many people with autism have problems understanding metaphors, sometimes interpreting them literally. They also have difficulty miming other people's actions. Often they display an eccentric preoccupation with trifles yet ignore important aspects of their environment, especially their social surroundings. Equally puzzling is the fact that they frequently show an extreme aversion to certain sounds that, for no obvious reason, set off alarm bells in their minds.

The theories that have been proposed to explain autism can be divided into two groups: anatomical and psychological. (Researchers have rejected a third group of theories—such as the "refrigerator mother" hypothesis—that blame the disorder on poor upbringing.) Eric Courchesne of U.C.S.D. and other anatomists have shown elegantly that children with autism have characteristic abnormalities in the cerebellum, the brain structure responsible for coordinating complex voluntary muscle movements. Although these observations must be taken into account in any final explanation of autism, it would be premature to conclude that damage to the cerebellum is the sole cause of the disorder. Cerebellar damage inflicted by a stroke in a child usually produces tremors, swaying gait and abnormal eye movements—symptoms rarely seen in autism. Also, one does not see any of the symptoms typical of autism in patients with cerebellar disease. It is possible that the cerebellar changes observed in children with autism may be unrelated side effects of abnormal genes whose *other* effects are the true causes of the disorder.

Perhaps the most ingenious of the psychological theories is that of Uta Frith of University College London and Simon Baron-Cohen of the University of Cambridge, who posit that the main abnormality in autism is a deficit in the ability to construct a "theory of other minds." Frith and Baron-Cohen argue that specialized neural circuitry in the brain allows us to create sophisti-

The Anatomy of Autism

People with autism show reduced mirror neuron activity in the inferior frontal gyrus, a part of the brain's premotor cortex, perhaps explaining their inability to assess the intentions of others. Dysfunctions of mirror neurons in the insula and anterior cingulate cortex may cause related symptoms, such as the absence of empathy, and deficits in the angular gyrus may result in language difficulties. People with autism also have structural changes in the cerebellum and brain stem.



cated hypotheses about the inner workings of other people's minds. These hypotheses, in turn, enable us to make useful predictions about others' behavior. Frith and Baron-Cohen are obviously on the right track, but their theory does not provide a complete explanation for the constellation of seemingly unrelated symptoms of autism. Indeed, saying that people with autism cannot interact socially because they lack a "theory of other minds" does not go very far beyond restating the symptoms. What researchers need to identify are the brain mechanisms whose known functions match those that are disrupted in autism.

One clue comes from the work of Giacomo Rizzolatti and his colleagues at the University of Parma in Italy, who in the 1990s studied neural activity in the brains of macaques while the animals were performing goal-directed actions. Researchers have known for decades that certain neurons in the premotor cortex—part of the brain's frontal lobe—are involved in controlling voluntary movements. For instance, one neuron will fire when the monkey reaches for a peanut, another will fire when the animal pulls a lever, and so on. These brain cells are often referred to as motor command neurons. (Bear in mind that the neuron whose activity is recorded does not control the arm by itself; it is part of a circuit that can be monitored by observing the signals in the constituent neurons.)

What surprised Rizzolatti and his co-workers was that a subset of the motor command neurons also fired when the monkey watched another monkey or a researcher perform the same action. For example, a neuron involved in controlling the reach-for-the-peanut action fired when the monkey saw one of his fellows making that movement. Brain-imaging techniques subsequently showed that these so-called mirror neurons also exist in the corresponding regions of the human cortex. These observations implied that mirror neurons—or, more accurately, the networks they are part of—not only send motor commands but also enable both monkeys and humans to determine the intentions of other individuals by mentally simulating their actions.

Later research showed that mirror neurons are located in other parts of the human brain, such as the cingulate and insular cortices, and that they may play a role in empathetic emotional responses. While studying the anterior cingulate cortex of awake human subjects, investigators found that certain neurons that typically fire in response to pain also fired when the person saw someone else in pain. Mirror neurons may also be involved in imitation, an ability that appears to exist in rudi-

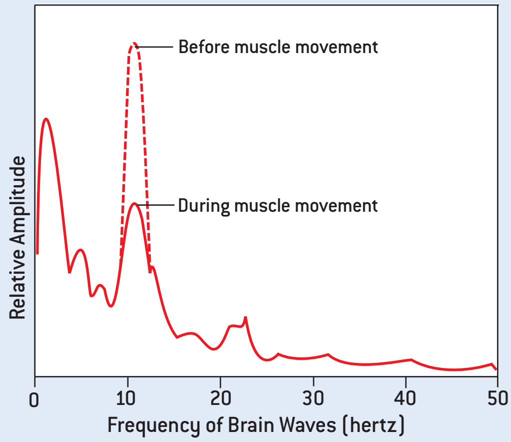
LUCY READING-IKKANDA

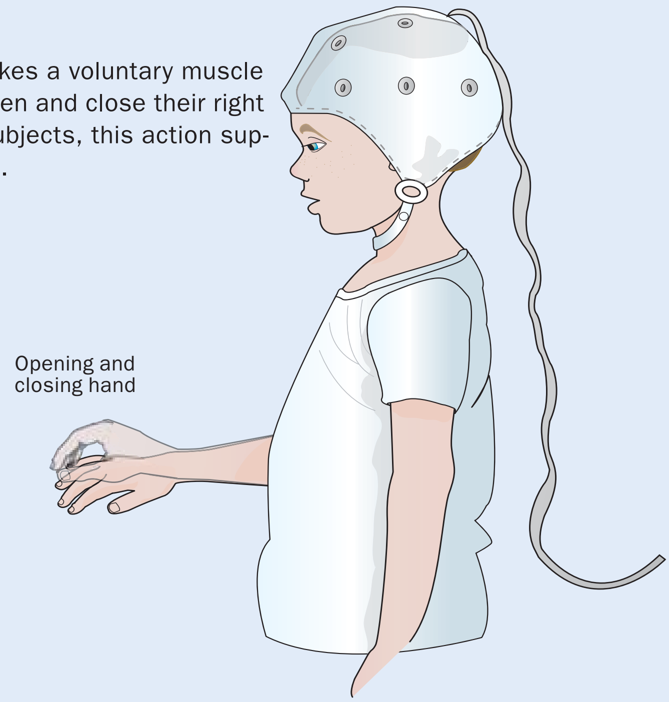
Focusing on Mu Waves

To study mirror neurons, researchers relied on the observation that the firing of neurons in the premotor cortex suppresses the mu wave, a component of the electroencephalogram (EEG) measurement of brain activity. (Mu waves range from eight to 13 hertz.) Investigators monitored the mu waves of children with autism and control subjects as they made voluntary muscle movements and then watched the same actions on video.

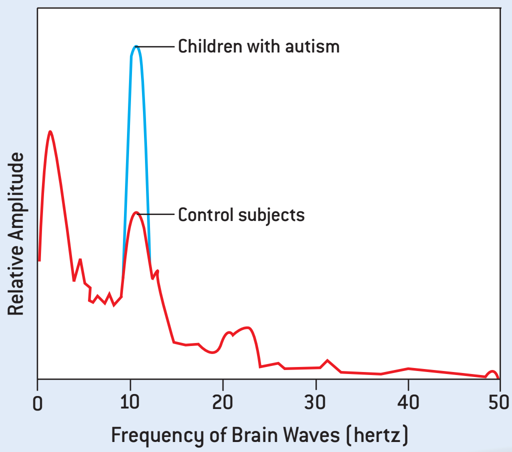
TAKING ACTION

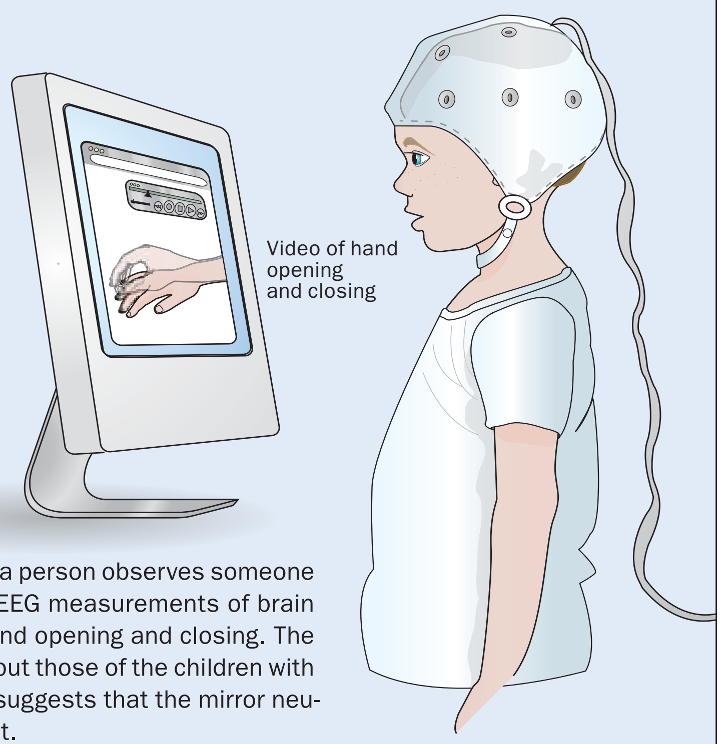
Motor command neurons fire whenever a person makes a voluntary muscle movement. Researchers asked all the subjects to open and close their right hands. In the children with autism and the control subjects, this action suppressed the amplitude of their mu waves, as expected.





SIMULATING ACTION





Mirror neurons in the premotor cortex also fire when a person observes someone else performing an action. The investigators took EEG measurements of brain activity while the subjects observed a video of a hand opening and closing. The mu waves of the control subjects plummeted (*red*), but those of the children with autism showed no suppression (*blue*). This finding suggests that the mirror neuron systems of the children with autism are deficient.

LUCY READING-IKKANDA

mentary form in the great apes but is most pronounced in humans. The propensity to imitate must be at least partly innate: Andrew Meltzoff of the University of Washington has shown that if you stick your tongue out at a newborn baby, the infant will do the same. Because the baby cannot see its own tongue, it cannot use visual feedback and error correction to learn the skill. Instead there must be a hardwired mechanism in the child's brain for mapping the mother's visual appearance—whether it be a tongue sticking out or a smile—onto the motor command neurons.

Children with autism often have problems interpreting proverbs and metaphors.

Language development in childhood also requires a remapping of sorts between brain areas. To imitate the mother's or father's words, the child's brain must transform auditory signals in the hearing centers of the brain's temporal lobes into verbal output from the motor cortex. Whether mirror neurons are directly involved in this skill is not known, but clearly some analogous process must be going on. Last, mirror neurons may enable humans to see themselves as others see them, which may be an essential ability for self-awareness and introspection.

Suppressing Mu Waves

What has all this to do with autism? In the late 1990s our group at U.C.S.D. noted that mirror neurons appear to be performing precisely the same functions that seem to be disrupted in autism. If the mirror neuron system is indeed involved in the interpretation of complex intentions, then a breakdown of this neural circuitry could explain the most striking deficit in people with autism, their lack of social skills. The other cardinal signs of the disorder—absence of empathy, language deficits, poor imitation, and so on—are also the kinds of things you would expect to see if mirror neurons were dysfunctional. Andrew Whiten's group at the University of St. Andrews in Scotland made this proposal at about the same time we did, but the first experimental evidence for the hypothesis came from our lab, working in collaboration with Eric L. Altschuler and Jaime A. Pineda of U.C.S.D.

To demonstrate mirror neuron dysfunction in children with autism, we needed to find a way to monitor the activity of their nerve cells without putting electrodes in their brains (as Rizzolatti and his colleagues did with their monkeys). We realized that we could do so using an electroencephalogram (EEG) measurement of the children's brain waves. For more than half a century, scientists have known that an EEG component called the mu wave is blocked anytime a person makes a voluntary muscle movement, such as opening and closing one's hands. Interestingly, this component is also blocked when a person watches someone else perform the same action. One of us (Ramachandran) and Altschuler suggested that mu-wave suppression might provide a simple, noninvasive probe for monitoring mirror neuron activity.

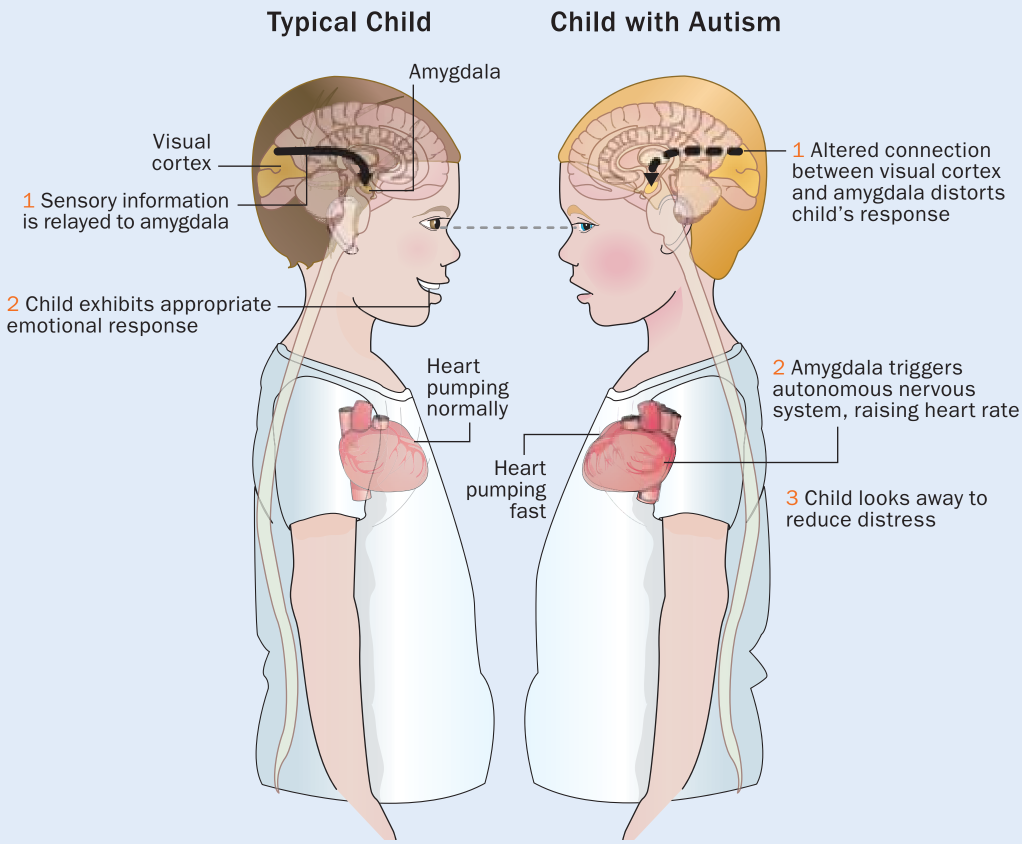
We decided to focus our first experiments on a high-functioning child with autism—that is, a child without severe cognitive impairments. (Very young, low-functioning children did not participate in this study because we wanted to confirm that any differences we found were not a result of problems in attention, understanding instructions or the general effects of mental retardation.) The EEG showed that the child had an observable mu wave that was suppressed when he made a simple, voluntary movement, just as in normal children. But when the child watched someone else perform the action, the suppression did not occur. We concluded that the child's motor command system was intact but that his mirror neuron system was deficient. This observation, which we presented at the annual meeting of the Society for Neuroscience in 2000, provided a striking vindication of our hypothesis.

One has to be careful, however, of generalizing from a single case, so our lab group later conducted a more systematic series of experiments in 10 high-functioning individuals with autism spectrum disorder and 10 age- and gender-matched control subjects. We saw the expected suppression of mu waves when the control subjects moved their hands and watched videos of a moving hand, but the EEGs of the subjects with autism showed mu suppression only when they moved their own hands.

Other researchers have confirmed our results using different techniques for monitoring neural activity. A group led by Riitta Hari of the Helsinki University of Technology found mirror neu-

The Salience Landscape Theory

To account for some of the secondary symptoms of autism—hypersensitivity, avoidance of eye contact, aversion to certain sounds, and so on—researchers have developed the salience landscape theory. In a typical child, sensory information is relayed to the amygdala, the gateway to the emotion-regulating limbic system. Using input from stored knowledge, the amygdala determines how the child should respond emotionally to each stimulus, creating a salience landscape of the child's environment. In children with autism, though, the connections between the sensory areas and the amygdala may be altered, thereby resulting in extreme emotional responses to trivial events and objects.



ron deficits in children with autism by employing magnetoencephalography, which measures the magnetic fields produced by electric currents in the brain. More recently, Mirella Dapretto of the University of California, Los Angeles, and her colleagues have reported similar findings using functional magnetic resonance imaging. Hugo Théoret of the University of Montreal has also found evidence for similar impairments using transcranial magnetic stimulation.

Taken together, these findings provide compelling evidence that people with autism have dysfunctional mirror neuron systems. Scientists do not yet know which genetic and environmental risk factors can prevent the development of mirror neurons or alter their function, but many research groups are now actively pursuing the hypothesis because it predicts symptoms that are unique to autism. In addition to explaining the primary signs of autism, deficiencies in the mirror neuron system can also account for some of the less well known symptoms. For instance, researchers have long known that children with autism often have problems interpreting proverbs and metaphors. When we told one of our subjects to "get a grip on yourself," he took the message literally and started grabbing his own body. Though seen in only a subset of children with autism, this difficulty with metaphors cries out for an explanation.

Understanding metaphors requires the ability

> If the child's mirror neuron functions are dormant rather than lost, it may be possible to revive them.

to extract a common denominator from superficially dissimilar entities. Consider the bouba/kiki effect, which was discovered by German-American psychologist Wolfgang Koehler more than 60 years ago. In this test, a researcher displays two crudely drawn shapes, one jagged and one curvy, to an audience and asks, "Which of these shapes is bouba and which is kiki?" No matter what languages the respondents speak, 98 percent will pick the curvy shape as bouba and the jagged one as kiki. This result suggests that the human brain is somehow able to extract abstract properties from the shapes and sounds—for example, the property of jaggedness embodied in both the pointy drawing and the harsh sound of kiki. We conjectured that this type of cross-domain mapping is analogous to metaphors and must surely involve neural circuits similar to those in the mirror neuron system. Consistent with this speculation, we discovered that children with autism perform poorly at the bouba/kiki test.

But which part of the human brain is involved in this skill? The angular gyrus, which sits at the crossroads of the brain's vision, hearing and touch centers, seemed to be a likely candidate—not only because it is strategically located but because nerve cells with mirror neuron–like properties have been identified there. When we studied nonautistic subjects with damage to this area of the brain, we found that many of them fail the bouba/kiki test and have a disproportionate difficulty understanding metaphors, just like people with autism. These results suggest that cross-domain mapping may have originally developed to aid primates in complex motor tasks such as grasping tree branches (which requires the rapid assimilation of visual, auditory and touch information) but eventually evolved into an ability to create metaphors. Mirror neurons allowed humans to reach for the stars, instead of mere peanuts.

Can the Mirrors Be Repaired?

The discovery of mirror neuron deficiencies in people with autism opens up new approaches to diagnosing and treating the disorder. For example, physicians could use the lack of mu-wave suppression (or perhaps the failure to mimic a mother sticking out her tongue) as a diagnostic tool to identify children with autism in early infancy, so that the currently available behavioral therapies can be started as quickly as possible. Timely intervention is critical; the behavioral therapies are much less effective if begun after autism's main symptoms appear (typically between ages two and four).

An even more intriguing possibility would be to use biofeedback to treat autism or at least alleviate its symptoms. Doctors could monitor the mu waves of a child with autism and display them on a screen in front of the patient. If the child's mirror neuron functions are dormant rather than completely lost, it may be possible for him or her to revive this ability by learning—through trial and error and visual feedback—how to suppress the mu waves on the screen. Our colleague Pineda is pursuing this approach, and his preliminary results look promising.

Another novel therapeutic approach might rely on correcting chemical imbalances that disable the mirror neurons in individuals with autism. Our group (including students Mikhi Horvath and Mary Vertinski) has suggested that specialized neuromodulators may enhance the activity of mirror neurons involved in emotional responses. According to this hypothesis, the partial depletion of such chemicals could explain the lack of emotional empathy seen in autism, and therefore researchers should look for compounds that stimulate the release of the neuromodulators or mimic their effects on mirror neurons. One candidate for investigation is MDMA, better known as ecstasy, which has been shown to foster emotional closeness and communication. It is possible that researchers may be able to modify the compound to develop a safe, effective treatment that could alleviate at least some of autism's symptoms. Another candidate is prolactin, a hormone known to promote social affiliation in animal studies.

(The Authors)

VILAYANUR S. RAMACHANDRAN and LINDSAY M. OBERMAN have investigated the links between autism and the mirror neuron system at the Center for Brain and Cognition at the University of California, San Diego. Ramachandran, director of the center, earned his Ph.D. in neuroscience from the University of Cambridge. A renowned expert on brain abnormalities, he has also studied the phenomena of phantom limbs and synesthesia, for which he won the 2005 Henry Dale Prize and a lifetime fellowship from the Royal Institution of Great Britain. Oberman is a graduate student in Ramachandran's laboratory at U.C.S.D., joining the group in 2002.

How Are Mirror Neurons Set Up?

If autism is caused by a mirror neuron deficiency, that raises an obvious question: Are these neurons hardwired by genes? One theory is that mirror neurons merely represent a form of associative learning. For example, every time a monkey reaches for a peanut, motor command neurons fire to move the monkey's hand. At the same time, the image of the reaching hand activates visual neurons in the monkey's brain. The firings of the two sets of neurons—motor and visual—become closely linked. As a result, the mere sight of peanut grabbing, even by another monkey, activates "mirror" motor neurons.

This theory predicts that if one were to use an optical trick to create the illusion that the monkey is seeing its *own* hand reach for a peanut (when the hand is not actually moving), the motor neurons in question should fire more vigorously than when the monkey sees another monkey's hand moving. Such an experiment has never been done, but the traditional view of mirror neurons—as structures that enable a monkey to "adopt another monkey's view"—predicts the opposite.

Another problem with the associative-learning theory is that only one third of the motor command neurons fire when a monkey watches another monkey grab a peanut. If mirror neurons are a matter of associative learning, why don't the other two thirds of the neurons "learn"?

We suggest that the term "mirror neuron" be extended beyond its original meaning as a linkage between motor and vision neurons. The near-universal identification of the words "bouba" and "kiki" with curved and jagged shapes, respectively, suggests mirror neuron–like mapping that enables the human brain to spontaneously abstract the common denominator between sounds and shapes. Perhaps all cross-domain mapping relies on such algorithms, which pave the way for more conceptual abstractions such as those involved in metaphor.

Consider the first time an infant mimics a mother's smile. Instead of being based on mirror neurons, this could be a reflex in response to a smile—like a sneeze in response to pepper. One way to find out would be to test whether infants can mimic an asymmetrical smile they have never seen before; this would eliminate the "reflex" explanation and implicate a hardwired mirror neuron–like mechanism.

Vocal mimicry might involve similar mechanisms. An internal brain template of the mother's vocalization might be set up during the first exposure. Through repeated attempts to match a trial vocalization (whether actually voiced or entirely internal) to the template, the baby's brain might "learn" how to set up mirror neurons even without the benefit of continued external feedback. On the other hand, if the imitation of a sound is immediate on the first exposure, it is more likely that these mirror neurons are hardwired rather than learned. We are currently exploring these possibilities.

—V.S.R. and L.M.O.

Mirror neurons may not explain autism symptoms such as emotional upheaval.

ED KASHI *Corbis*

We are also developing an experimental treatment using mirrors. A child with autism would be taught to reach for a toy hidden under a table, guided only by the mirror reflection of his or her hand and the toy. The perfect synchrony between the child's own motor commands and the movements of the "other child" in the mirror might provide "double dose" stimulation to help revive dormant mirror neurons.

Such treatments, however, may offer only partial relief, because other symptoms of autism cannot be explained by the mirror neuron hypothesis—for example, repetitive motions such as rocking to and fro, avoidance of eye contact, hypersensitivity, and aversion to certain sounds. In an attempt to determine how these secondary symptoms might arise, our lab group (in collaboration with William Hirstein of Elmhurst College and Portia Iversen of Cure Autism Now, a nonprofit foundation based in Los Angeles) has developed what we call the salience landscape theory.

When a person looks at the world, he or she is confronted with an overwhelming amount of sensory information—sights, sounds, smells, and so on. After being processed in the brain's sensory areas, the information is relayed to the amygdala, which acts as a portal to the emotion-regulating limbic system. Using input from the individual's stored knowledge, the amygdala determines how the person should respond emotionally—for example, with fear (at the sight of a burglar), lust (on seeing a lover) or indifference

(Some symptoms of autism **cannot be explained** by the mirror neuron hypothesis.)

(when facing something trivial). Messages cascade from the amygdala to the rest of the limbic system and eventually reach the autonomic nervous system, which prepares the body for action. If the person is confronting a burglar, for example, his heart rate will rise and his body will sweat to dissipate the heat from muscular exertion. The autonomic arousal, in turn, feeds back into the brain, amplifying the emotional response. Over time, the amygdala creates a salience landscape, a map that details the emotional significance of everything in the individual's environment.

Our group decided to explore the possibility that children with autism have a distorted salience landscape, perhaps because of altered connections between the cortical areas that process sensory input and the amygdala or between the limbic structures and the frontal lobes that regulate the resulting behavior. As a result of these abnormal connections, any trivial event or object could set off an extreme emotional response—an autonomic storm—in the child's mind. This hypothesis would explain why children with autism tend to avoid eye contact and any other novel sensation that might trigger an upheaval. The distorted perceptions of emotional significance might also explain why many children with autism become intensely preoccupied with trifles such as train schedules while expressing no interest at all in things that most children find fascinating.

We found some support for our hypothesis when we monitored autonomic responses in a group of 37 children with autism by measuring the increase in their skin conductance caused by sweating. In contrast with the control subjects, the children with autism had a higher overall level of autonomic arousal. Although they became agitated when exposed to trivial objects and events, they often ignored stimuli that triggered expected responses in the control group.

But how could a child's salience landscape become so distorted? Investigators have found that nearly one third of children with autism have had temporal lobe epilepsy in infancy, and the proportion may be much higher given that many epileptic seizures go undetected. Caused by repeated random volleys of nerve impulses traversing the limbic system, these seizures could eventually scramble the connections between the visual cortex and the amygdala, indiscriminately enhancing some links and diminishing others. In adults, temporal lobe epilepsy results in florid emotional disturbances but does not radically affect cognition; in infants, however, the seizures may lead to a more profound disability. And, like autism, the risk of temporal lobe epilepsy in infancy appears to be influenced by both genetic and environmental factors. Some genes, for example, could make a child more susceptible to viral infections, which could in turn predispose the child to seizures.

The salience landscape theory could also provide an explanation for the repetitive motions and head banging seen in children with autism: this behavior, called self-stimulation, may somehow damp the child's autonomic storms. Our studies found that self-stimulation not only had a calming effect but also led to a measurable reduction in skin conductance. Hirstein is now developing a portable device that could monitor an autistic child's skin conductance; when the device detects autonomic arousal, it could turn on another device, called a squeeze vest, that provides a comforting pressure by gently tightening around the child's body.

Our two candidate theories for explaining the symptoms of autism—mirror neuron dysfunction and distorted salience landscape—are not necessarily contradictory. It is possible that the same event that distorts a child's salience landscape—the scrambled connections between the limbic system and the rest of the brain—also damages the mirror neurons. Alternatively, the altered limbic connections could be a side effect of the same genes that trigger the dysfunctions in the mirror neuron system. Further experiments are needed to rigorously test these conjectures. The ultimate cause of autism remains to be discovered. In the meantime, our speculations may provide a useful framework for future research. M

(Further Reading)

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Mindful of

On the way to learning that one thing can represent another, young children often conflate the real item and its symbol. These errors show how difficult it is to start thinking symbolically

Photographs prove tricky to many toddlers because they have not mastered dual representation: awareness that a symbolic object is itself (in this case, a photograph) as well as a representation of something else (a sneaker). Many try to interact with objects in photographs, such as attempting to put a foot in a shoe.

Photographs by Randy Harris

Symbols

BY JUDY S. DeLOACHE

About 20 years ago I had one of those wonderful moments when research takes an unexpected but fruitful turn. I had been studying toddler memory and was beginning a new experiment with two-and-a-half- and three-year-olds. For the project, I had built a small-scale model of a room that was part of my lab. The real space was furnished like a standard living room, with an upholstered couch, an armchair, a cabinet, and so on. The miniature items were as similar as possible: they were the same shape and material, covered with the same fabric and arranged in the same positions. For the study, a child watched as we hid a miniature toy—a plastic dog we dubbed "Little Snoopy"—in the model, which we referred to as "Little Snoopy's room." We then encouraged the child to find "Big Snoopy," a large version of the toy "hiding in the same place in his big room." We wondered whether children could use their memory to figure out where to find the toy in the large room.

The three-year-olds were very successful. After they observed the small toy being placed behind the miniature couch, they ran into the real room and found the large toy behind the real couch. But the two-and-a-half-year-olds, much to my and their parents' surprise, failed abysmally. They cheerfully ran into the big room, but most of them had no idea where to look, even though they remembered where the tiny toy was hidden in the miniature room and could readily find it there.

Their failure to use what they knew about the model to draw an inference about the room indicated that they did not appreciate the relation between the model and room. I soon realized that my memory study was instead a study of symbolic understanding and that the younger children's failure might be telling us something interesting about how and when youngsters acquire the ability to understand that one object can stand for another.

What most distinguishes humans from other creatures is our ability to create and manipulate a wide variety of symbolic representations. This capacity enables us to transmit information from one generation to another, making culture possible, and to learn vast amounts without having direct experience—we all know about dinosaurs despite never having met one. Because of the fundamental role of symbolization in almost everything we do, perhaps no aspect of human development is more important than becoming symbol-minded. What could be more fascinating, I concluded, than finding out how young children begin to use and understand symbolic objects and how they come to master some of the symbolic items ubiquitous in modern life?

Pictures Come to Life

The first type of symbolic object infants and young children master is pictures. No symbols seem simpler to adults, but my colleagues and I have discovered that infants initially find pictures perplexing. The problem stems from the duality inherent in all symbolic objects: they are real in and of themselves and, at the same time, are representations of something else. To understand them, the viewer must achieve dual representation: he or she must mentally represent the object as well as the relation between it and what it stands for.

A few years ago I became intrigued by anecdotes suggesting that infants do not appreciate the dual nature of pictures. I would hear of a baby who tried to pick up a depicted apple or to fit a foot into a photograph of a shoe. My colleagues—David H. Uttal of Northwestern University, Sophia L. Pierroutsakos of St. Louis Community College and Karl S. Rosengren of the University of Illinois—and I decided to investigate even though we assumed such behaviors would be rare and therefore difficult to study. Fortunately, we were wrong.

We began testing infants' understanding of pictures in a very simple way. We put a book containing highly realistic color photographs of individual objects in front of nine-month-olds. To our surprise, every child in the initial study, and most in our subsequent studies, reached out to feel, rub, pat or scratch the pictures. Sometimes the infants even grasped at the depicted objects as if trying to pick them up off the page.

We had a unique opportunity to see how universal this response was when anthropologist Alma Gottlieb of the University of Illinois took some of our books and a video camera to a remote Beng village in Ivory Coast. Beng babies sat on the ground or in their mother's lap as chickens and goats wandered around and other children and villagers played, worked, talked and laughed nearby. Yet the Beng babies, who had almost certainly never seen a picture before, manually explored the depicted objects just as the American babies had.

The confusion seems to be conceptual, not perceptual. Infants can perfectly well perceive the difference between objects and pictures. Given a choice between the two, infants choose the real thing. But they do not yet fully understand what pictures are and how they differ from the things depicted (the "referents"), and so they explore: some actually lean over and put their lips on the nipple in a photograph of a bottle, for instance. They only do so, however, when the depicted object is highly similar to the object it represents, as in color photographs. The same confusion occurs for video images. Pierroutsakos and her colleague Georgene L. Troseth of Vanderbilt University found that nine-month-olds seated near a television monitor will reach out and grab at objects moving across the screen. But when objects bear less resemblance to the real thing—as in a line drawing—infants rarely explore them.

By 18 months, babies have come to appreciate that a picture merely represents a real thing. Instead of manipulating the depicted object, they point to it and name it or ask someone else for the name. In 2004 Melissa A. Preissler, now at the University of Edinburgh in Scotland, and Susan Carey of Harvard University provided a good example of this development. The two researchers used a simple line drawing of a whisk to teach 18- and 24-month-olds the word for this object that they had not seen before. Most of the children assumed the word referred to the object itself, not just to the picture of it. They interpreted the picture symbolically—as standing for, not just being similar to, its referent.

One factor we think contributes to the decline of manual exploration of pictures is the development of inhibitory control. Throughout the first years of life, children become increasingly capable of curbing impulses. This general developmental change is supported by changes in the frontal cortex. Increased inhibitory control presumably helps infants restrain their impulse to interact directly with pictures, setting the stage for them to simply look, as adults do.

Experience with pictures must play a role in this development as well. In an image-rich society, most children encounter family photographs and picture books on a daily basis. From such interactions, children learn how pictures differ from objects, and they come to appreciate images as targets of contemplation and conversation, not action.

> (Symbolic representation enables us to learn vast amounts about dinosaurs despite never having met one.)

Nevertheless, it takes several years for the nature of pictures to be completely understood. John H. Flavell of Stanford University and his colleagues have found, for example, that until the age of four, many children think that turning a picture of a bowl of popcorn upside down will result in the depicted popcorn falling out of the bowl.

Pictures are not the only source of symbol confusion for very young children. For many years, my colleagues and students and I watched toddlers come into the lab and try to sit down on the tiny chair from the scale model—much to the astonishment of all present. At home, Uttal and Rosengren had also observed their own daughters trying to lie down in a doll's bed or get into a miniature toy car. Intrigued by these remarkable behaviors that were not mentioned in the scientific literature, we decided to study them.

Gulliver's Errors

We brought 18- to 30-month-old children into a room that contained, among other things, three large play objects: an indoor slide, a child-size chair and a car toddlers could get inside of and propel around the room with their feet. After a child had played with each of the objects at least twice, he or she was escorted from the room. We then replaced the large items with identical miniature versions, only about five inches tall. When the child returned, we did not comment on the switch and let him or her play spontaneously.

We then examined films of the children's behavior for what we came to call scale errors: earnest attempts to perform actions that are clearly impossible because of extreme differences in the relative size of the child's body and the target object. We were very conservative in what we counted as a scale error.

Scale errors, another example of failed dual representation, are common among 18- to 30-month-olds. They interact with small objects as they would with larger versions. This boy kept falling off the chair. (In experiments, objects can be even smaller.)

Almost half the children committed one or more of these mistakes. They attempted with apparent seriousness to perform the same actions. Some sat down on the little chair: they walked up to it, turned around, bent their knees and lowered themselves onto it. Some simply perched on top, others sat down so hard that the chair skittered out from under them. Some children sat on the miniature slide and tried to ride down it, usually falling off in the process; others attempted to climb the steps, causing the slide to tip over. (With the chair and slide made of sturdy plastic and being so small, the toddlers faced no danger of hurting themselves.) A few kids tried to get into the tiny car; they opened the door and attempted—often with remarkable persistence—to force a foot inside.

Interestingly, most of the children showed little or no reaction to their failed attempts. A couple seemed a bit angry, a few looked sheepish, but most simply went on to do something else. We think the lack of reaction probably reflects the fact that toddlers' daily lives are full of unsuccessful attempts to do one thing or another.

Our interpretation of scale errors is that they originate in a dissociation between the use of visual information for planning an action and for controlling its execution. When a child sees a miniature, visual information—the object's shape, color, texture, and so on—activates the child's mental representation of its referent. Associated with that memory is the motor program for interacting with the large object and other similar objects. In half the children we studied, this motor program was presumably activated but then inhibited, and the children did not attempt to interact with the miniature in the same way.

But in the other half the motor routine was not inhibited. Once the child began to carry out the typical motor sequence, visual information about the actual size of the object was used to accurately perform the actions. Some children, for instance, bent over the tiny chair and looked between their legs to precisely locate it; those trying to get into the miniature car first opened its door and then tried to shove their foot right in. The children relied on visual information linking the replica to the normal-size object, but in executing their plan, they used visual information about the miniature's actual size to guide their actions. This dissociation in the use of visual information is consistent with influential theories of visual processing—ones positing that different regions of the brain handle object recognition and planning versus the execution and control of actions.

The Magical Machine

Scale errors involve a failure of dual representation: children cannot maintain the distinction between a symbol and its referent. We know this because the confusion between referent and sym-

(The Author)

JUDY S. DELOACHE specializes in early cognitive development—specifically of symbolic thinking—at the University of Virginia, where she is professor of psychology. DeLoache also holds an appointment in psychology at the University of Illinois, where she earned her doctorate and has taught since the late 1970s.

Two-year-olds have difficulty appreciating the symbolic relation between a model of a room and the room itself. This boy can see the toy hidden behind the plant in the model but does not know to look for a toy behind the real plant.

bolic object does not happen when the demand for dual representation is eliminated—a discovery I made in 1997 when Rosengren, Kevin F. Miller, now at the University of Michigan at Ann Arbor, and I convinced two-and-a-half-year-olds—with the full consent of their parents, of course—that we had a device that could miniaturize everyday objects.

Using our amazing shrinking machine, we hoped to see if the need to think of an object in two ways at once was at the heart of children's symbol difficulties. If a child believes that a machine has shrunk an object or a room, then in the child's mind the miniature is the thing itself. There is no symbolic relation between room and model, so children should be able to apply what they know about the big version to the little one.

We used the powers of our device to shrink toys and a large tent. In front of the child, we placed a toy—a troll doll with vivid purple hair—in a tent and aimed the shrinking machine at the tent. The child and experimenter then decamped to another room to wait while the machine did its work. When they returned to the lab, a small tent sat where the big one had been.

When we asked the children to search for the toy, they immediately looked in the small tent. Believing the miniature to actually be the original tent after shrinking, they successfully retrieved the hidden toy. Unlike in our scale model experiment, they had no dual representation to master: the small tent was the same as the large tent, and thus the toy was where it should be, according to the toddlers' view of the world.

Understanding the role of dual representation in how young children use symbols has important practical applications. One has to do with the practice of using dolls to interview young children in cases of suspected sexual abuse. The victims of abuse are often very young children, who are quite difficult to interview. Consequently, many professionals—including police officers, social workers and mental health professionals—employ anatomically detailed dolls, assuming that a young child will have an easier time describing what happened using a doll. Notice that this assumption entails the further assumption that a young child will be able to think of this object as both a doll and a representation of himself or herself.

These assumptions have been called into question by Maggie Bruck of Johns Hopkins University, Stephen J. Ceci of Cornell University, Peter

A. Ornstein of the University of North Carolina at Chapel Hill and their many colleagues. In several independent studies, these investigators have asked preschool children to report what they remember about a checkup with their pediatrician, which either had or had not included a genital check. Anatomically detailed dolls were sometimes used to question the children, sometimes not. In general, the children's reports were more accurate when they were questioned without a doll, and they were more likely to falsely report genital touching when a doll was used.

Common failures show that using dolls to interview young children about sexual abuse may be faulty.

Based on my research, I suspected that very young children might not be able to relate their own body to a doll. In a series of studies in my lab using an extremely simple mapping task, my former graduate student Catherine Smith placed a sticker somewhere on a child—on a shoulder or foot, for example—and asked the child to place a smaller version of the sticker in the same place on a doll. Children between three and three and a half usually placed the sticker correctly, but those younger than three were correct less than half the time. The fact that these very young children cannot relate their own body to the doll's in this extremely simple situation that does not have memory demands or emotional involvement supports the general case against the use of anatomically detailed dolls in forensic situations with young children. (Because of many demonstrations akin to this one, the use of dolls with children younger than five is viewed less favorably than in the past and has been outlawed in some states.)

Educational Ramifications

The concept of dual representation has implications for educational practices as well. Teachers in preschool and elementary school classrooms around the world use "manipulatives"—blocks, rods and other objects designed to represent numerical quantity. The idea is that these concrete objects help children appreciate abstract mathematical principles. But if children do not understand the relation between the objects and what they represent, the use of manipulatives could be counterproductive, as some research suggests.

Meredith Amaya of Northwestern University, Uttal and I are now testing the effect of experience with symbolic objects on young children's learning about letters and numbers. Using blocks designed to help teach math to young children, we taught six- and seven-year-olds to do subtraction problems that require borrowing. We taught a comparison group to do the same using pencil and paper. Both groups learned to solve the problems equally well—but the group using the blocks took three times as long to do so. A girl who used the blocks offered us some advice after the study: "Have you ever thought of teaching kids to do these with paper and pencil? It's a lot easier."

Dual representation also comes into play in popular books for children that include flaps that can be lifted to reveal pictures, levers that can be pulled to animate images, and so forth.

Graduate student Cynthia Chiong and I reasoned that these manipulative features might distract children from information presented in the book. Accordingly, we recently used different types of books to teach letters to 30-month-old children. One was a simple, old-fashioned alphabet book, with each letter clearly printed in simple black type accompanied by an appropriate picture—the traditional "A is for apple, B is for boy." Another book had a variety of manipulative features. The children who had been taught with the plain book subsequently recognized more letters than did those taught with the more complicated book. Presumably the children could more readily focus their attention with the plain 2-D book.

As these various studies show, infants and young children are confused by many aspects of symbols that seem intuitively obvious to adults. They have to overcome hurdles on the way to achieving a mature conception of what symbols represent, and today many must master an ever expanding variety of symbols. Perhaps a deeper understanding of the different stages of becoming symbol-minded will enable researchers to address learning problems that might stem from difficulty grasping the meanings of symbols. M

(Further Reading)

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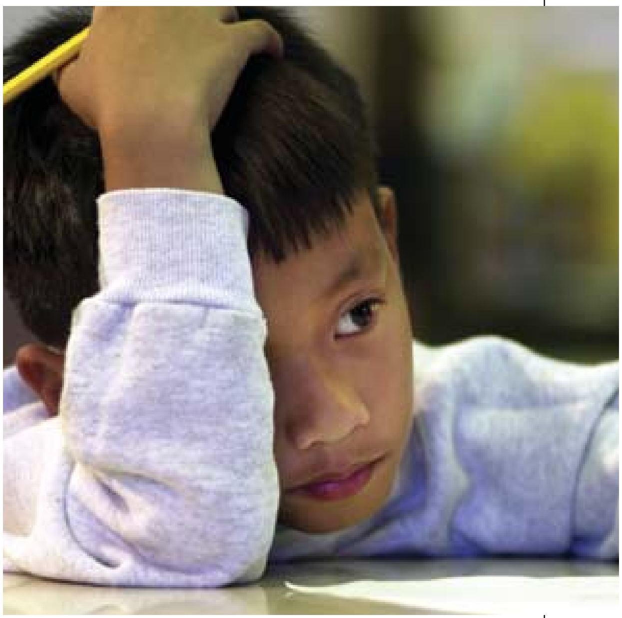
- Images of children making symbol-related errors can be seen at **www.faculty.virginia.edu/childstudycenter/home.html**

Informing the ADHD Debate

The latest neurological research has injected much needed objectivity into the disagreement over how best to treat children with attention-deficit disorders

By Aribert Rothenberger and Tobias Banaschewski



THINKSTOCK

From the moment Julia entered first grade, she appeared to spend most of her time daydreaming. She needed more time to complete assignments than the other children did. As she moved through elementary school, her test scores deteriorated. She felt increasingly unable to do her homework or follow the teacher's instructions in class. She made few real friends and said her teachers got on her nerves. She complained that her parents pressured her all day long and that nothing she did was right.

Julia was actually very friendly and talkative, but a lack of self-control made others feel uneasy around her. By age 14, she found that concentrating on assignments seemed impossible. She constantly lost her belongings. Neuropsychological exams showed Julia was of average intelligence but repeatedly interrupted the tests. She was easily distracted and seemed to expect failure in everything she did. So she just gave up. Ultimately Julia was diagnosed with attention-deficit hyperactivity disorder (ADHD) and was treated with methylphenidate, one of the standard drugs for her condition. The medication helped Julia organize her life and tackle her schoolwork more readily. She says she now feels better and is much more self-confident.

Julia's symptoms constitute just one profile of a child with ADHD. Other girls and boys exhibit similar yet varied traits, and whereas medication has helped in many cases, for just as many it provides no relief. With the number of cases increasing every year, debate over basic questions has heightened: Is ADHD overdiagnosed? Do drugs offer better treatment than behavior modification? Recent progress in understanding how brain activity differs in ADHD children is suggesting answers.

What Causes ADHD?

ADHD is diagnosed in 2 to 5 percent of children between the ages of six and 16; approximately 80 percent are boys. The typical symptoms of distractibility, hyperactivity and agitation occur at all ages, even in adults who have the condition, but with considerable disparity. Children often seem forgetful or impatient, tend to disturb others and have a hard time observing limits. Poor impulse control manifests itself in rash decision making, silly antics and rapid mood swings. The child acts before thinking. And yet ADHD children often behave perfectly normally in new situations, particularly those of short duration that involve direct contact with individuals or are pleasurable or exciting, like watching TV or playing games.

GETTY IMAGES

Precursor behaviors such as a difficult temperament or sleep and appetite disorders have often been found in children younger than three who were later diagnosed with ADHD, but no definitive diagnosis can be made in those first three years. Physical restlessness often diminishes in teenagers, but attention failure continues and can often become associated with aggressive or antisocial behavior and emotional problems, as well as a tendency toward drug abuse. Symptoms persist into adulthood in 30 to 50 percent of cases.

Longitudinal epidemiological studies demonstrate that ADHD is no more common today than in the past. The apparent statistical rise in the number of cases may be explained by increased public awareness and improved diagnosis. The condition can now be reliably identified according to a set of characteristics that differentiate it from age-appropriate behavior. Nevertheless, debates about overdiagnosis, as well as preferred treatments, are sharper than ever.

Neurologists are making headway in informing these debates. For starters, researchers using state-of-the-art imaging techniques have found differences in several brain regions of ADHD and non-ADHD children of similar ages. On average, both the frontal lobe and the cerebellum are smaller in ADHD brains, as are the parietal and temporal lobes. ADHD seems to be the result of abnormal information processing in these brain regions, which are responsible for emotions and control over impulses and movements.

Yet these variations do not indicate any basic mental deficiency. Currently physicians see the disorder as an extreme within the natural variability of human behavior. On neuropsychological tests such as letter-sequence recognition on a computer, ADHD children have varied but frequently slower reaction times. The reason, experts now believe, is that neural information processing—the foundation of experience and behavior—may break down, especially when many competing demands suddenly flood the brain. In this circumstance or when faced with tasks requiring speed, thoroughness or endurance, the performance of ADHD brains decreases dramatically compared with the brains of other children. A lack of stimulation, on the other hand, quickly leads to boredom.

The attention deficit is particularly evident whenever children are asked to control their behavior—stopping an impulsive action or maintaining a high level of performance in a given task. The problem is not so much a lack of attention per se but a rapid drop in the ability to continually pay attention.

A different phenomenon, however, gives hyperactive children the uncontrollable urge to move. Together with the cerebellum, which coordinates movement, various control systems within and underneath the cerebral cortex are responsible for motor functions. This region is where the neurons of the motor cortex, the basal ganglia and the thalamus come together. The motor cortex represents the final stage of neural processing, after which motor impulses are sent to muscles. When activity in these regions is not balanced, children have difficulty preparing for, selecting and executing movements because they cannot adequately control or inhibit their motor system. Complex movements that require precise sequencing are initiated too early and then overshoot their target. Hyperactivity also often goes hand in hand with deficits in fine-motor coordination and an inability of children to stop speech from bursting forth uncontrollably.

In general, the underlying trait of impulsivity is linked to the development of the brain's so-called executive function: the ability to plan and to monitor working memory. Executive function develops over time as the brain matures. In children with ADHD, however, it tends to remain rudimentary. Anatomically, the executive function stems from neural networks in the prefrontal cortex—the so-called anterior attentional system. Together with the posterior attentional system, located largely in the parietal lobes, it tracks and regulates behavior.

While trying to navigate life without a strong ability to monitor and plan, ADHD children are often in constant battle with their emotions. They are barely able to control their feelings, and they do not endure frustration well. They easily become excited and impatient and tend toward hostility. They also find it hard to motivate themselves for certain tasks. And they are apt to grasp at the first reward that comes their way, no matter how small, rather than wait for a larger, more attractive payoff.

Dopamine plays an important role in the limbic system, which addresses emotional challenges, and ADHD children typically have low levels of this neurotransmitter. Normally, for example, dopamine release strengthens the neural connections that lead to a desired behavior when a reward stimulus is presented. But when dopamine is absent, rewards that are minor or presented at the wrong time have no effect.

Genes or Environment

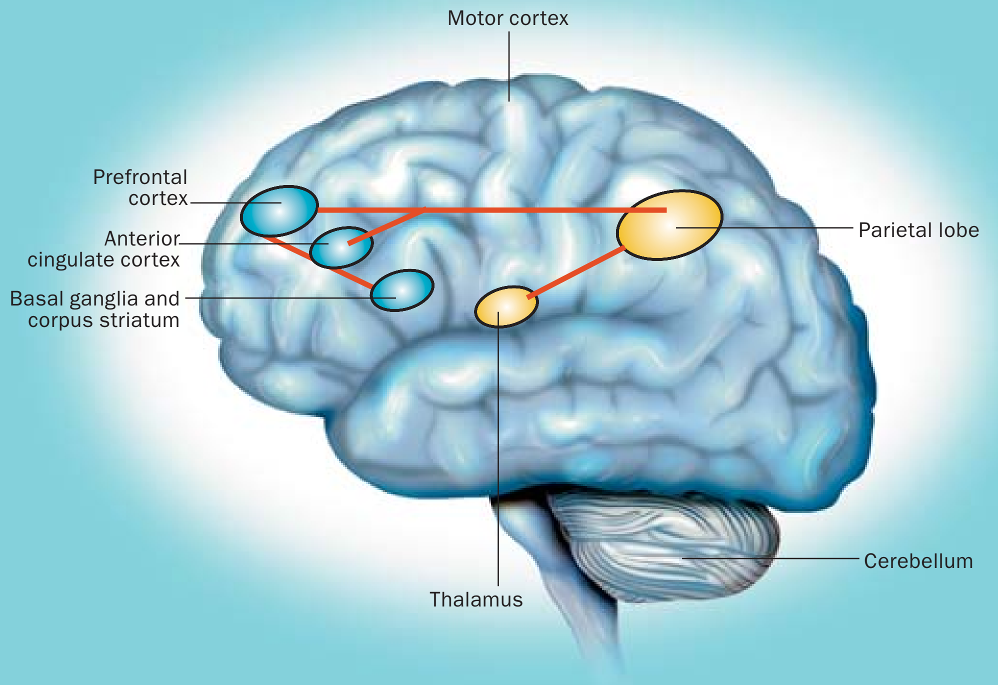
One question that arises from all these findings is why specific brain regions are smaller than others and why certain brain functions are weak or unbalanced. Genes may play a considerable role. Comprehensive metastudies of parents and children and identical and fraternal twins, such as those conducted by Anita Thapar, then at the University of Manchester in England, in 1999, Philip Asherson of King's College in London in 2001, and Susan Sprich of Massachusetts General Hospital in 2001, show that heredity greatly influences the occurrence of ADHD. For example, children of parents who have had ADHD are far more likely to suffer similar symptoms. The studies indicate that approximately 80 percent of ADHD cases can be traced to genetic factors.

> Studies indicate that approximately 80 percent of ADHD cases can be traced to genetic factors.

As a result, researchers have been busily trying to identify which genes might be different in ADHD children. High on the suspect list are genes involved in transferring information between neurons. This group includes genes for proteins that influence the circulation of dopamine at the synapses between neurons—for example, proteins that clear away old messenger molecules so new ones can come through. So far researchers have found that receptor mediation of the dopamine signal is too weak in some patients, and dopamine reuptake is too rapid in others.

The genetics work seems to indicate that behavior problems are associated with insufficient regulation of dopamine metabolism, which derails neural information processing. The neurotransmitter norepinephrine may play a role, too. Although the genetic links between norepinephrine and its receptors and transporters are not as clearly understood as those for dopamine, medications such as atomoxetine that inhibit norepinephrine reuptake by neurons do improve symptoms.

When coupled, the neurotransmitter and brain-imaging evidence imply that the brains of ADHD children may be organized and function differently from an early age. These organic dis-



Uncommon activity in various brain regions is associated with hyperactive behavior in ADHD children. Regions are typically part of the anterior attentional system (*blue*), which depends on the neurotransmitter dopamine, or the posterior attentional system and norepinephrine (*yellow*).

parities may actually be the cause of behavioral changes and not a consequence of them, as has sometimes been suggested. Another piece of evidence is that in some cases, as children mature, certain physiological peculiarities—such as the size of the corpus striatum—become normal, and ADHD fades.

Still, ADHD cannot yet be tied neatly to known physical, genetic factors. Experts believe that the gene loci discovered to date explain at most 5 percent of problematic behaviors. If more fundamental gene variations are at fault, they have not yet been found. The probability of developing a hyperactivity disorder depends on a combination of many different genes.

Furthermore, there is wide variability in the degree to which these genetic factors are expressed. That means environmental influences must certainly play a role. For example, alcohol and nicotine consumption by a mother during pregnancy tend to increase the risk of ADHD in offspring, much the same way they contribute to extreme prematurity, low birth weight and food allergies.

On the other hand, it is also true that mothers with a genetic predisposition to ADHD have a propensity to smoke and drink during pregnancy. They tend to make basic child-rearing errors, too, such as failing to establish clear rules and effective limits. A chaotic household can strengthen biological ADHD tendencies, leading to a vicious cycle.

Other psychosocial factors, including a nonsupportive school environment, marital crises or psychological problems arising between parents, and poor parent-child attachment can also transform a latent tendency into a full-blown disorder.

Medication Dispute

Recent findings about deficits in brain function and neurotransmitters make it clear why certain drugs are likely treatments. And yet the role of environment suggests that behavioral therapy can also be effective. Today uncertainty surrounds both options, and the increasing use of medication has proved divisive. Opinion runs from euphoric endorsement to outright rejection.

The body of evidence suggests that neurotransmitter systems need to be targeted. Psychostimulants such as amphetamine sulfates and methylphenidate, marketed under such names as Ritalin, have had widespread success. Numerous clinical studies show that these medications can decrease or eliminate behavioral disorders in 70 to 90 percent of patients.

(The Authors)

ARIBERT ROTHENBERGER and TOBIAS BANASCHEWSKI are both in the clinic for child and adolescent psychiatry at the University of Goettingen in Germany. Rothenberger is a professor and director of the clinic. Banaschewski is the clinic's chief physician.

GEHIRN & GEIST/SIGANIM

Latest Leap

Neurofeedback is the newest treatment alternative that therapists are exploring to combat ADHD. It is based on the finding that the electrical brain activity of ADHD children often differs from that of their peers. In this scheme, children play special computer games to learn how to consciously influence their brain waves—and therefore their behavior. For example, they can make themselves calmer and more attentive by strengthening certain electrical activity and decreasing other activity. Sounds, music or movie clips reward them when they can elicit a desired change.

In one game (*photograph*), a child wearing electrodes watches a cartoon of a pole-vaulting mouse. The mouse can only clear the bar when the pole turns red. This feat occurs when the child concentrates, but the pole turns blue when the child does not.

Children in neurofeedback therapy usually undergo three or four 30- to 40-minute sessions a week for six to 10 weeks. Attention, concentration, impulsivity and mild forms of hyperactivity frequently improve. A child's feelings of self-esteem also improve because he sees that he can control his own behavior. Many succeed in transferring the concentration skills they develop to their schoolwork. *—A.R. and T.B.*

Administering stimulants to hyperactive children might seem counterintuitive. Yet these substances fix the genetically based dopamine imbalance in the parts of the brain responsible for self-regulation, impulse control and perception. In effect, they prevent the overly rapid reuptake of dopamine at synapses. Other substances with similar modes of action, such as the norepinephrine reuptake inhibitor atomoxetine, work equally well.

Many parents are understandably nervous about subjecting their children to a long-term regimen of medication. News that Ritalin use may be implicated in Parkinson's disease, a dopamine deficiency illness, has added to the worry. Such a connection was suspected because rats that received methylphenidate before sexual maturity exhibited fewer than normal dopamine transporters in their striatum. But to date, not a single case of Parkinson's has been attributed to the use of Ritalin during childhood, and on average Parkinson's patients do not have a history of taking psychostimulants more frequently than other people. Nevertheless, many parents may fear that long-term treatment with psychoactive drugs could leave their child vulnerable to drug or medication abuse in the future.

In 2003, however, Timothy E. Wilens and his colleagues at Harvard Medical School laid these concerns to rest with a large-scale metastudy. It turns out that the use of psychostimulants significantly *reduces* the risk of future abuse. In comparing ADHD adults with comparable symptoms, those who had not received ADHD medications as children were three times more likely to succumb to drug addiction later in life than those who had received medication.

Drugs Plus Behavior

This does not mean that physicians should prescribe drugs lightly. And under no circumstances should doctors, parents or patients rely exclusively on medication. Studies show that adding behavioral therapy greatly enhances improvements. It also can teach children how to overcome any kind of problematic behavior that might arise in their lifetime. Children learn how to observe and control themselves. Unless ADHD erupts in its most extreme form, behavioral therapy should be the initial treatment of choice. If a child shows no significant signs of improvement after several months, a drug regimen can then be considered.

For the youngest children—those of preschool age—psychostimulants should generally be avoided. Parents should instead try to work daily with their children on their behavior. They would also do well to draw on the expertise of preschool

ARIBERT ROTHENBERGER

teachers, who see many different children with a wide range of challenges.

A comprehensive examination conducted in 2000 by the National Institute of Mental Health rated the effectiveness of medical and behavioral treatments of ADHD. Conducted over two years, the Multimodal Treatment Study of Children with ADHD included 579 ADHD children at six different university medical centers. The principal investigators divided the test subjects, all of whom were between the ages of seven and nine, into four groups that had different treatment plans. The results strongly suggest that a combination of drug and behavioral therapies leads to the highest success:

- Routine daily treatment with prescribed medication normalized behavior in 25 percent of children treated.
- Intensive behavioral therapy without medication ended with 34 percent of patients exhibiting no further remarkable symptoms.
- Carefully tailored medical treatment with accompanying counseling for the child and parents helped 56 percent of the children.
- A combination of medication and behavioral therapy resulted in a success rate of 68 percent.

(Studies strongly suggest that a combination of drug and behavioral therapies leads to the highest success.)

Always Count to 10

These findings allow us to draw concrete conclusions about how parents and educators might best help ADHD children. With or without drugs, it is imperative that children be taught how to handle tasks with more organization and less impulsivity. One common tool, for example, is teaching them to count to 10 before carrying out an impulse, such as jumping up from a table at school. Wall posters or cards shaped like stop signs can remind children to use the various devices they have learned in the heat of a moment. Older children and teenagers can learn how to make detailed plans and how to follow through when complicated tasks threaten to shut them down—for example, when they must straighten a messy bedroom.

Parents also need aids for dealing with trying situations. They can receive guidance in parent training programs that focus on their child-rearing skills as well as their child's interactions within the family. One common recommendation is to set up written schedules with children so that getting ready for school, for example, does not turn into a contest every morning. Clear rules, specific expectations and known consequences as well as reward points for desired behaviors can all be effective. Particularly with teenagers, parents and even siblings should be included in family therapy.

As neuroscience progresses, therapists continue to try to refine which mixes of drugs and behavioral therapy are best for which types of ADHD. More work is needed. Little is known, for example, about what occurs in the brains of ADHD children between birth and the time they enter school. One conclusion has become increasingly clear, however: the varying combinations of behaviors cannot be grouped into a picture of a single disorder. Researchers are now trying to define subgroups that are more coherent in terms of symptoms and neurological causes. To this end, they are looking at other disturbances that are often associated with attention deficit or hyperactivity; approximately 80 percent of ADHD children suffer from at least one other challenge, such as nervous tics, antisocial behavior, anxiety, or reading and spelling problems.

In the meantime, as parents and teachers do the best they can, they must remember that ADHD children possess many positive traits. They tend to be free-spirited, inquisitive, energetic and funny, as well as intelligent and creative. Their behavior is often spontaneous, helpful and sensitive. Many ADHD children are talented multitaskers, last-minute specialists and improvisationalists. Parents and educators should encourage these strengths and let their children know whenever possible that these qualities are highly valued. That will help them feel less under attack, a relief that all by itself can help them begin to turn the corner. M

(Further Reading)

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Just a Bit Different

With special training early in life, children born with Down syndrome have a higher chance of developing into independent individuals

By Ingelore Moeller

In the mid-1800s English doctor John Langdon Down was appointed director of a home outside London for mentally handicapped children, where he studied their symptoms. In 1862 he described the case of one of his wards who was short and had stubby fingers and unusual eyelids. The boy's condition was later labeled with his surname. But the genetic cause of Down syndrome was not uncovered for another century. In 1959 French pediatrician Jérome Lejeune discovered that these children have three copies of chromosome 21, instead of the standard two.

Chris Burke, an actor with Down syndrome, played a similarly affected character on *Life Goes On,* a series that stressed the need to accept such individuals into society.

For too long, people with Down syndrome, or trisomy 21, have been dismissed as "retarded" and thus incapable of having rich lives. But that view has begun to change. Psychologists, doctors and special-education teachers now realize that a diagnosis at infancy does not necessarily mean a child will have few options in life—as long as he or she receives special training early. And socially, Down syndrome children are finally being accepted as unspectacular, everyday kids, in part thanks to the 1990s hit ABC television series *Life Goes On,* starring an actor with Down syndrome, Chris Burke, who today is 41.

Physical limitations continue to challenge these individuals. Poor muscle tone (which often causes the tongue to protrude from the mouth); joint trouble; pale, sensitive skin; and vision, hearing and thyroid problems are prevalent. About half suffer from congenital heart defects. But medical progress in the past two decades has doubled the average life expectancy from 25 to 50 years. For those without heart defects, life expectancy is even higher. Yet for most, a rewarding mental and social life is their greatest desire—and their greatest challenge.

Third Copy Interference

Trisomy 21 is the most common chromosomal abnormality in humans. It affects one in every 800 to 1,000 live births. Today more than 350,000 Americans have Down syndrome. But why does having three copies of chromosome 21 cause the condition? With a completed map of the human genome, researchers are in hot pursuit of an answer.

Soon after scientists in the Human Genome Project finished describing chromosome 21 in 2000, they confirmed that within this chromosome are the genes that cause both Down syndrome and Alzheimer's disease. Neurologists had previously discussed a connection between the two disorders, because both involve an inadequate production of the neurotransmitter acetylcholine, one of the brain's messenger molecules. In a 2003 research review, Nancy Roizen of the Cleveland Clinic and David Patterson of the University of Denver focused on a particular gene that is crucial to energy production and oxygen utilization inside cells. They speculated that a defect in this system leads to the production of aggressive oxygen free radicals—molecules that damage cells—which may play a role in both Down syndrome and Alzheimer's.

In 2004 Guilherme Neves and Andrew Chess, now at the Center for Human Genetic Research at Massachusetts General Hospital, tracked the roles played by other genes on chromosome 21—in this case using a fruit fly as the model. They found a gene—dubbed *Dscam* (Down syndrome cell adhesion molecule)—that appears to give every nerve cell a unique identity during prebirth development, making sure that each cell ends up in the right location in the brain and body. Neves

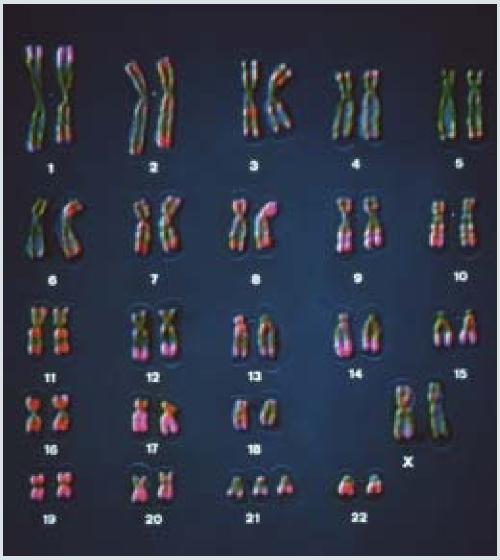
LAUREN SHEAR *Science Photo Library/Photo Researchers, Inc. (preceding pages)*; COURTESY OF EVERETT COLLECTION *(this page)*

People with Down syndrome don't "suffer" from their disorder—only from bad treatment by others.

Chromosome 21: Three Instead of Two

Our genetic blueprint is stored in the chromosomes found in the nucleus of every cell in our bodies. There are 23 different bundles of DNA that normally exist in pairs, one copy each from the mother and father. They determine what people look like, how they develop and which diseases they may be vulnerable to.

A woman's egg and a man's sperm each contain a single set of the 23 chromosomes. The pairing occurs during fertilization, when the egg and sperm merge. On occasion, however, an egg or sperm may supply two copies of a particular chromosome, giving a fertilized egg—and thus every cell in the body of the future individual—three copies of that chromosome instead of two, and 47 chromosomes in total rather than 46. Most trisomies result in such devastating consequences that the embryo cannot survive and is rejected. But chromosome 21 is the smallest of the 23, and it seems that three copies of it may be less problematic; embryos with trisomy 21—the genetic cause of Down syndrome—do survive.



Caprice of nature: Individuals with Down syndrome have three copies of the smallest chromosome, number 21, instead of two and therefore have 47 total chromosomes rather than 46.

Geneticists have found that in 95 percent of babies born with trisomy 21, all body cells have 47 chromosomes. About 2 percent have mosaic trisomy, in which only some body cells have the third copy. The remaining 3 percent have translocational trisomy, the only inheritable form of Down syndrome; in this case, only parts of chromosome 21 are duplicated and attached to other chromosomes.

Babies with Down syndrome can be born into any family and to parents of any age or nationality. One well-documented risk factor, however, is maternal age. Ernest B. Hook of the University of California, Berkeley, estimates that the risk of having an infant with Down syndrome is one in 1,500 for a 20-year-old woman but rises to approximately one in 20 for a 45-year-old mother-to-be. *—I.M.*

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and Chess hypothesize that a different version of the gene may affect humans similarly. Because people with trisomy 21 possess an additional copy of this gene, the oversupply may hinder the establishment of correct connections among brain cells during fetal development.

Shortly before birth, the brain starts checking over its entire network and sorting out the superfluous connections, which are then pared down. But in one explanation, with trisomy 21 many of the unproductive connections endure. They constitute "dead ends" that slow the physical growth, learning and thought processes of people with Down syndrome.

Delayed Development

After birth, trisomy 21 children go through essentially the same developmental steps as other children, but their rate of progress is slower and varies much more widely. The range has been well documented by researchers such as Hellgard Rauh, a psychologist at the University of Potsdam in Germany, who has observed the progress of more than 30 Down syndrome children over several years.

Rauh has found that their mental development during the first three years of life proceeds, on average, about half as fast as normal, meaning most two-year-olds with Down syndrome have reached the same milestones as average 12- to 14-month-old babies. In the following years, the rate of mental development slows to about one third of that for normal children. Grasping, crawling and walking prove to be especially difficult hurdles in the first two or three years. Physical development lags behind, although after the third year the rate of mental development may catch up to a degree. Speech is often a problem; most Down syndrome children at the age of five

(The Author)

INGELORE MOELLER is an ethnologist, economist and medical journalist based in Lemgo, Germany. She also serves as a publicity consultant for the Eben Ezer Foundation, a religious institution benefiting people with mental disabilities.

More than 350,000 Americans have trisomy 21. Helping them obtain jobs and build households will dissolve long-standing prejudices, enriching everyone's lives.

SUSAN VAN ETTEN *Photo Edit*

or six—just before starting elementary school—are only beginning to speak in two- or three-word sentences. For example, when they want their favorite toy they will just say, "Ball!" and they will express their fear of a neighbor's pet by crying, "Dog!" Delays in language continue to plague many young people with Down syndrome right into adulthood.

For many trisomy 21 children, abstract thinking, such as dealing with numbers or geometric shapes, can be hard. They also have trouble with visual and linguistic symbolism, even with such simple concepts as same versus different and more versus less.

On the other hand, when Wolfgang Jantzen, a special-education expert who retired in 2005 from the University of Bremen in Germany, tested affected 11-year-olds—whose language skills were at about a four-year-old level—on spatial tasks, they performed almost age-appropriately. For example, he would give them a one-step problem such as "Place the yellow circle in front of the blue square," and they responded well. But if he added, "Before you pick up the yellow circle, touch the blue square," most of them would fail. The children had no trouble with the spatial placement, but the time-order sequence baffled them.

Also characteristic of children with Down syndrome is slower mental processing. Virtually all their reactions occur with a longer-than-usual time delay, which must be taken into account when working or living with them. Otherwise, misunderstandings will quickly mount. For example, a father may ask his seven-year-old son whether he would like a hamburger at supper time. The boy may not respond immediately. The father may interpret the silence as a "no" and ask, "Would you rather have cheese?" "Yes," the boy might answer—and when he gets a plate with cheese, he may burst into tears because he was expecting the hamburger.

One tricky aspect of Down syndrome is that the children often realize they cannot accomplish many things that other kids their age can. They therefore seek to protect themselves when faced with challenges and, as Rauh explains, may

Children whose mothers are relaxed seem at ease. Those with controlling mothers seem insecure.

choose from several different strategies. Some try, with a combination of charm and feigned helplessness, to get other people to rescue them from difficult situations. Others manipulate their environment by clowning or throwing tantrums. And some will become honestly sad and simply give up. This resignation can be deep enough to set off psychosomatic disorders, such as chronic stomachaches.

Lively and Imaginative

While psychologists learn more about the thoughts going through the minds of Down syndrome children, parents, friends and teachers must still grapple with how to help these boys and girls reach their highest mental and social potential. It is becoming clear that the best way to encourage such growth is to interact with the children in lively, imaginative ways.

This positive support starts with the parents. Rauh observed that some mothers responded to their children's initiatives in play in a relaxed manner; they were attentive and friendly without trying to control what was happening, which cultivated an especially close attachment between child and mother. Other mothers remained detached from their son's or daughter's play, which left the child detached as well. When mothers seemed to have a need to be constantly involved by controlling and limiting the child's activity, it made the child insecure. Children who felt confident of their mother's interest behaved in a more relaxed way and presumably would adapt better to their surroundings.

Special "games" can help infants as well. Jutta Hatzer, a special-education teacher in Bremen, emphasizes simple measures designed to reinforce self-awareness during a child's first year of life. She demonstrated one exercise during a session with a one-year-old boy, Tom. She stood Tom in a large bucket filled halfway with dry beans, which reached his waist. The beans acted like little massage balls for the baby, who sat quietly and happily in his snug lair. "The enclosure provides security," Hatzer explains. "He can feel his body, sense his limits and get a firsthand notion of himself."

After a while, Hatzer encouraged Tom to grasp the beans. Everything proceeded slowly, step by step—the boy needed plenty of time to deal with each new situation. Hatzer sang simple, made-up songs describing each step ("Tom is in the bucket"). She repeated each phrase several times and soothed Tom with both words and gestures. Through this continuous communication and play the child learned to understand links between his internal and external worlds. This kind of early support, which for Tom began shortly after he was born, is designed to bolster his mental development so that it will be easier for him to learn to walk and talk later.

Some therapists recommend that caregivers use hand and arm gestures in conjunction with words. The children seem to learn gestures very quickly, helping them grasp the meaning of spoken words. For example, the boy mentioned earlier who got cheese instead of a hamburger might have better understood an accompanying gesture for "hamburger"—such as pretending to hold and bite the burger—which could have prevented the misunderstanding.

To bring Down syndrome children along, adults must also be careful not to appear standoffish or afraid of them. People with Down syndrome do not "suffer" from their disorder—only from inappropriately high demands from their environment. They are just a little different. They think differently, handle emotions differently, view things differently, look a bit different and sometimes react in ways we do not expect. They are full of originality and creativity but often do need a lot of encouragement for it to show. If those around them can accept them and be positive, they will develop into full personalities who know what they want and don't want.

One-year-old Tom is still too young to express his wishes. For him, being close to his mother is most important. She takes him into her arms, and he presses his little face into her neck. "What I hope for is that he can remain as happy and content as he is now and that he will always be well treated," she says. "That would be the nicest thing." **M**

(Further Reading)

- Information about and for people with Down syndrome and their families can be found at the Trisomy 21 Online Community at **http://trisomy21online.com/**
- Research advancements are tracked by the National Down Syndrome Society at **www.ndss.org/**

Stopping the BULLIES

School can be torture for children who are targeted by abusive students

By Mechthild Schaefer

The boys attack Basini almost every night, yanking him out of bed and pushing him up the stairs to the attic. No teacher will hear his screams there. They force him to undress, then whip his back. Naked and defenseless, the boy cowers while his tormentors force him to cry, "I'm a beast!" During the day other students surround him in the school yard and shove him around until he collapses, bloodied and soiled.

Robert Musil's *The Confusions of Young Törless*, a fictional study of puberty in a turn-of-the-century Austrian boarding school, was published in 1906. The impulses that seethed behind the walls of the Imperial and Royal Military Academy may sound like embarrassing relics of a bygone era, but they are not. Raw violence by a group against one individual, covered up by fellow students and avoided by teachers, still happens in schools today. And bullying in general—physical and psychological intimidation and humiliation, as well as the regular spreading of rumors—is more pervasive than communities, school officials or parents would like to believe.

Unfortunately, it has taken shocking violence

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to focus more attention on solving the problem. The 1999 shootings at Columbine High School in Littleton, Colo., were a fatal attempt to strike back by two outcasts who had been bullied by popular jocks at the school. Bullying was one factor that drove Jeffrey Weise into a life of isolation before he went on a retaliatory shooting spree at Red Lake High School in Minnesota in March 2005, killing nine others and then himself. And every year adolescents commit suicide, leaving behind notes like that from a 14-year-old Canadian girl: "If I try to get help, it will get worse.... If I ratted, there would be no stopping them." Schools must take more aggressive steps to stop the torment, and the most fundamental measure is to better understand what motivates bullies in the first place.

Systematic Abuse

Psychologists and behavior researchers have only seriously studied mobbing—group bullying—among students since the beginning of the 1980s, led in large part by Norwegian psychologist Dan Olweus of the University of Bergen. In his pioneering study of Swedish and Norwegian students, Olweus concluded that children can be very skilled in systematically using their social clout at the expense of weaker schoolmates. The goal is to enhance their own position.

Mobbing thrives in hierarchical settings because they allow dominance and strength to reign as the measure of an individual's social value. It is therefore not surprising that prisons and military bases, with their emphasis on rules and rank, are often the scenes of mobbing. Schools, in which older or stronger children can lord their age and power over younger or weaker ones, share similar traits. Thrown into a diversity of personalities, certain individuals try to create a social structure that confers on them an advantage. And usually that power is wielded to abuse others.

According to the National Center for Education Statistics, in 2005 about 28 percent of U.S. students ages 12 to 18 reported that they had been bullied at school in the past six months. (And certainly far more never said a word.) The likelihood of bullying was highest in the younger grade levels: 37 percent of sixth graders, 28 percent of ninth graders and 20 percent of 12th graders reported that they had been picked on. These percentages are higher than those found in school crime surveys done in 1999, 2001 and 2003—in which students were simply asked whether they had been bullied. The 2005 survey posed a series of questions on bullying and provided respondents with more examples of bullying.

Sufferers must usually face the harassment alone. Other boys and girls generally take the side of the perpetrators, fearing that they could be next in line. Or they pretend events did not happen and keep their mouths shut. Few find the courage to stand up for their fellow students. In the end, mobbing affects the entire school atmosphere, not just the bullies and their targets.

Power-Hungry Predators

To learn about what motivates the abusers, a research team (of which I was a part) at the Uni-

> (Young bullies often have had tougher physical discipline from parents and viewed more TV violence.)

Intimidation can be psychological as well as physical, through taunting, gossip and the regular spreading of rumors.

BANANA STOCK/AGE FOTOSTOCK

versity of Munich conducted a long-term study of 288 second and third graders from different elementary schools in southern Germany. We questioned them about their experiences: What kinds of children were apt to fall prey to bullies? How did the rest of the class react? We interviewed the same children six years later, when they were in the eighth and ninth grades. We asked if former victims were still targeted. And we asked how victims dealt with such problems now that they were teenagers.

Our first important finding was that bullies can be identified early in elementary school: even at a tender age, they are able to organize a mob against certain individuals. They appear to always be on the lookout for new kids to pick on. And they find it difficult to abandon their roles over time; perpetrators tend to remain perpetrators over many months and even years.

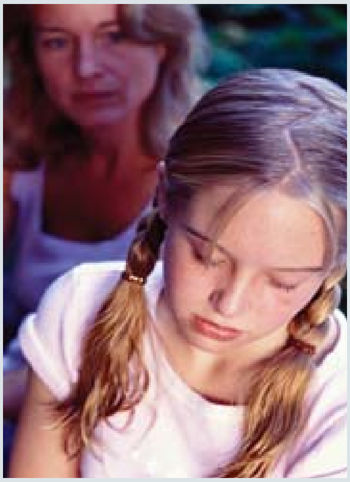
Bullies are usually very dominant children who have learned early on that they can become the leader of a group by being aggressive. Their modus operandi is to humiliate a student who is physically or psychologically susceptible so as to rise to the top of the social order. They try to force others to kowtow to them by acting tough, and other children may oblige simply out of fear. Often the bullies have learned about the power of aggression at home. Researchers at the University of Arizona who studied more than 500 middle school students found that the children most likely to engage in bullying had experienced more forceful physical discipline from their parents, had viewed more TV violence and had fewer adult role models. To a degree, they had learned by example.

Likewise, we encountered eight-year-olds who, by their own statements and those of their contemporaries, had been the butt of mobbing for quite a while. They endured harassment and exclusion yet never put up resistance or informed adults about their situation. The consequences can be long-lasting. In earlier studies we had shown that children who are harassed by schoolmates over a lengthy period are often unable to defend themselves against hostility and react to attack with anxiety and helplessness. Such terrible experiences make it all the more likely that they will fall into the traps set by bullies.

When we asked the same questions six years later, the students' answers bore this out. After asking the 13- and 14-year-olds which kids they liked and which they did not, we developed a preference profile that gave us a good sense of an individual's social ranking in a class. The result was surprising. In contrast to the bullies' relative lower standing during elementary school, they had actually become very popular with their classmates. Their victims, on the other hand, got few sympathy points.

How do certain students get selected, abused and finally rebuffed by many of their peers? Are these children disliked because they are mobbed, or are they mobbed because they are disliked? It seems both dynamics are at play. Even if the victims were able to avoid some of the bullying when

Is Your Child a Victim?



RONNIE KAUFMAN *Corbis*

Most children will not tell their parents if they are being bullied, because they are afraid that their parents will somehow blame them or that word will get out that they "told" and the bullies will heap even more abuse on them. But parents can look for certain suspicious indicators:

- Unexplained reluctance to go to school.
- Fearfulness or unusual anxiety.
- Sleep disturbances and nightmares.
- Vague physical complaints, such as headaches or stomachaches, especially on school days.
- Belongings that are "lost" or come home damaged.

If you suspect your child may be a victim, do not ask him or her directly. You might ask your child such questions as: What goes on during lunch hour? What is it like walking to school or riding the bus? Are there any children who are bullies?

Be a good listener. Allow your child time to explain how he or she feels. If you suspect your child may be a victim, state clearly that it is not his or her fault. Then ask yourself if the events are serious enough to discuss with a teacher, principal or even the police.

By Sarah Shea, associate professor of developmental pediatrics at Dalhousie University in Halifax, Nova Scotia. Adapted from "Parents' Primer on School Bullying," by Richard B. Goldbloom, in Reader's Digest Canada Online, March 9, 2005.

(The Author)

MECHTHILD SCHAEFER is an associate professor of educational psychology at the Ludwig Maximilian University of Munich in Germany.

Former victims more frequently have trouble forming trusting relationships with other adults.

they were younger, school often became something of a torture chamber as they got older. Their peers acted as if they were not there or responded with outright rejection and whispered behind their backs. The bullies escalated this game, insulting and making fun of them. Many of the target children came to identify with the underdog role and became the playthings of whoever persecuted them. And the longer the intimidation went on, the more the loyalty of others was lost.

This dynamic is aggravated by supposedly disinterested bystanders, an insight explored in depth in the early 1990s by psychologist Debra Pepler of York University in Toronto. After questioning students about mobbing, she and her team shadowed them with hidden cameras and microphones. The researchers discovered that almost 60 percent of the supposedly neutral students were on friendly terms with the bullies. Almost half the "uninvolved" observers eventually graduated to jeering the victims and egging on the perpetrators. Numerous other studies have demonstrated that a large majority of students in the end go along with the bullies or become perpetrators themselves.

Helping the Victim

Further understanding of what makes bullies prevail will help break down their sources of power. In the meantime, though, more should be done to minimize the long-lasting effects on those who are hurt. In 2002 my colleagues and I interviewed 884 men and women from Germany, the U.K. and Spain, more than 25 percent of whom recalled having suffered physical and psychological attacks by other children when they

Stopping the Bully

By not showing weakness, a child can lessen chances that a bully will target him or her. Some tactics for encounters:

- Stand straight and tall; look the bully straight in the eye.
- Be polite but firm. Tell the bully, "Stop it" or "Leave me alone."
- Do not cry or show that you are upset. Walk away if you cannot hide your fear.
- Report events to a trusted adult.

MICHAEL NEWMAN *Photo Edit*

Parents can help children who have been bullied at school in these ways:

- Contact your child's school anonymously and ask if it has a policy for handling bullies.
- If assured that an inquiry will not expose your child to greater risk, inform the school of specific events that transpired, including date, time and place.
- Follow up with school administrators. Ask what action has been taken and how your child will be kept safe if his or her identity is accidentally exposed.

By Cindi Seddon, principal of Pitt River Middle School in Port Coquitlam, B.C., and co-founder of Bully B'ware Productions.

Students often side with the perpetrator, look away during confrontations or pretend events did not happen, fearing they could be next in line.

BERND WEISSBROD *DPA/Landov*

attended school. Their bitterness at being excluded and threatened continued to affect them in their adult lives. Former mobbing victims more frequently had trouble developing trusting relationships and lacked confidence when interacting with other adults. Their expectations of themselves and others were lower than average. The one positive note was that their previous experience was not usually repeated in their work lives, although mobbing in the workplace—the ganging up of subordinates or superiors through rumor, innuendo, intimidation, humiliation, discrediting and isolation—does happen.

The long-term consequences of mobbing make clear that early prevention is critical. The tricky task of intervening at the right moment falls to teachers and parents—who may not be prepared to act appropriately. For example, Norwegian students told a government ombudsman that adults do not even recognize their predicaments in the classroom. Our team's work bore this out: on questioning, teachers admitted to feeling unable to make sense of complex student relationships.

Nevertheless, at a minimum teachers can set standards by their own behavior. How they act in their position of power has an effect on the students. For example, they should avoid all derogatory comments and never return homework in descending grade order. Weak students should not be criticized in class. If a teacher makes it clear that he or she is there for all the students and treats each one alike, they will see this as a sign not to exclude others from the group.

The subject of mobbing certainly belongs in the curriculum, too—perhaps in combination with antiviolence training or special projects. Another way to improve how students deal with one another socially is to appoint student mediators who can help resolve conflicts in a class of students. Initiatives such as these promote cohesion within the group so that bullies find it more difficult to undermine the school community by singling out and accosting its weaker members.

In Musil's story, the young Basini found no help. The three perpetrators went unpunished. The other students covered for the bullies, and the teachers were caught in a web of lies, charges and countercharges. In the end, Basini was expelled. Real life for a real victim can be much worse. M

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The Teen Brain,

Hard at Work
No, really

By Leslie Sabbagh

It is late in the evening rush hour, typical stop-and-go traffic. Finally, there is a break; the tightly packed group around you is soon cruising together at 55 mph. Suddenly, you see brake lights flare up ahead. As you prepare to brake, you glance in the rearview mirror and see an alarming sight—a car closing way too fast on your rear fender. The teenage driver looks panicked, one hand clutching the steering wheel, the other hand clenching a cell phone. You brace for the terrible impact …

We are quick to blame adolescents for getting themselves into predicaments that adults believe could be easily avoided. But recent research indicates that simple irresponsibility may not be the full explanation. When teenagers perform certain tasks, their prefrontal cortex, which handles decision making, is working much harder than the same region in adults facing the same

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circumstances. The teen brain also makes less use of other regions that could help out. Under challenging conditions, adolescents may assess and react less efficiently than adults.

Understanding the capabilities and limitations of the brain at different developmental stages is crucial for education and psychological assessment. Ironically, although the teenage years are widely recognized as a period of tremendous growth and change, the mental capabilities of teens have been less studied than those of children or adults. As more work is completed, it is becoming apparent that society should not be fooled into thinking that a teen has the mental prowess of an adult just because he or she looks and, most of the time, behaves like one. Brain processes that support cognitive control of behavior are not yet mature. Add stressors to the mix—like a sudden highway jam—and a teen can be an accident waiting to happen.

In stressful conditions, such as a sudden traffic jam, a teen's prefrontal cortex may become overloaded, causing slow or bad decisions—an accident waiting to happen.

AGE FOTOSTOCK

Self-Control Difficulties

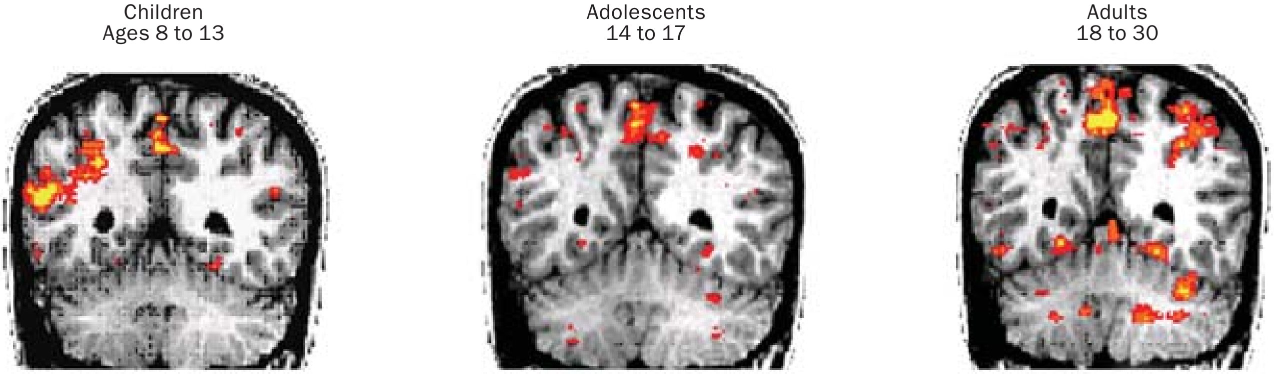
As recent studies underscore, differences in the prefrontal cortex—responsible for the so-called executive function that underlies planning and voluntary behavior—may be one of the most important distinctions between adolescents and adults. Beatriz Luna, director of the Laboratory of Neurocognitive Development at the University of Pittsburgh, has pinpointed differences by scanning the brains of teens and adults with functional magnetic resonance imaging (fMRI) during demanding tests of the visual-motor system.

In one setup, subjects faced a computer that flashed lights randomly. They were told either to rapidly focus on the lights or to try to avoid looking at them. Luna found that, when trying to block a strong reflexive tendency and make a considered response, "teens used more of their prefrontal cortex resources than adults did." Indeed, the amount of prefrontal cortex employed was similar to what adult brains use when performing a much more complex task. This excessive reliance, Luna says, "can lead to error, especially when difficulty increases."

Psychologists distinguish between two types of behavior control: exogenous and endogenous. Exogenous control is reflexive, generated in response to external stimuli—for example, focusing on lights as they appear on the screen. Endogenous control is voluntary and generated by an internal plan—trying not to look at the lights. A mature prefrontal cortex makes it easier for endogenous behavior to override exogenous behavior. In the traffic scenario, the exogenous response of the teen who suddenly realizes he is going to hit your rear bumper would be to freeze and scream, whereas the endogenous response would be to brake hard and steer out of the way. But for teen brains, deliberately overriding the exogenous reaction is more difficult than it is for adult brains.

Experts such as Luna maintain that although adolescents can at times demonstrate adult-level cognitive control of decision making, this endogenous power is only beginning to mature. In the visual-motor tests, she explains, subjects must use the prefrontal cortex to tell the rest of the brain how to behave. "Adolescents show similar capabilities of inhibition compared with adults, but the fMRIs show that they are using up pre-

Bad decisions and risky behavior may result from an immature prefrontal cortex, not just rebellion.



In a test of visual control, adolescents (*center*) called on more brain regions than children yet far fewer than adults, who better distributed the workload.

frontal cortex like crazy," Luna notes. Adults call on other parts of the brain "to collaborate and better distribute the workload," she adds.

The implication is that if something unexpected occurs in an already stressful situation, an adolescent may exhaust his or her prefrontal cortex resources. Adults can better handle the stress by tapping other brain regions. And in everyday life, general overtaxing of the prefrontal cortex may undermine executive function, impairing planned behaviors and choices. That may explain why adolescents exhibit impulsive or thoughtless behavior. For example, Luna says, it may be easier for adults to suppress bad responses to peer pressure. They may be better able to keep themselves in line, rather than succumbing to temptation.

Overloading the Cortex

Full maturation of executive function occurs only as a completely integrated, collaborative brain system emerges, in the late teens and even in the early 20s, according to psychologists. But in adolescents, a key contributor that helps to guide voluntary behavior—working memory—is also still developing. Luna's fMRI images support the conclusion that adolescents are not as efficient in recruiting areas that support working memory.

Weak integration has also been found by Susan F. Tapert, associate professor of psychiatry at the University of California, San Diego, who investigated spatial working memory in earlier and later adolescence. Tapert tested 25 young teens (ages 12 to 14) and 24 older teens (ages 15 to 17) using fMRI. Older adolescents, she says, "showed more intense and widespread dorsolateral prefrontal activation as they performed a working-memory task, and used more right inferior parietal cortex but less superior parietal cortex than younger adolescents."

Tapert infers that older adolescents recruit different neural networks and employ different strategies to perform the same job. Older teens used regions that suggested they solved the task through a verbal strategy rather than through simple (yet taxing) rote spatial rehearsal, which appears to be how the younger teens performed the task. Over the course of adolescence, the brain involves more areas in general and distributes certain tasks to specialized regions, thereby reducing the neuronal effort necessary to achieve the same level of performance. "I was surprised with the magnitude of change we observed across this relatively narrow age range," Tapert says.

Early adolescents can perform well on spatial working-memory tests, but it appears they need to engage in more neural activity to do so. They also become much less efficient if they are stressed when asked to perform an additional task. Only at the end of adolescence, Tapert says, is spatial working memory efficiently distributed across brain regions.

Still Pruning

Recent structural MRI images of adolescent brains lend credence to the notion that regions of the teen brain involved in decision making and

(The Author)

LESLIE SABBAGH is a science journalist who specializes in medicine and aerospace. She has flown on combat medevac missions in Iraq and NASA science and microgravity flights.

behavior control undergo significant physical changes. Jay N. Giedd, a psychiatrist and investigator in the Child Psychiatry Branch at the National Institute of Mental Health, has shown that the dorsolateral prefrontal cortex, important in controlling impulses, undergoes synaptic pruning—the elimination of unnecessary connections between neurons. This results in more efficient transmission of nerve impulses.

Most researchers agree that pruning is a fundamental mechanism for brain maturation. So is adding more myelin—insulation around the axons that send signals from neuron to neuron. Both changes translate into improved brain function. Synaptic pruning increases efficiency of local computations, whereas myelination speeds up neuronal transmissions. As a result, Luna notes, the prefrontal cortex is more able to impose voluntary and planned behaviors.

Giedd evaluates data from ongoing MRI studies conducted at the Child Psychiatry Branch. A recent study draws from a pool consisting of 307 children and adolescents who underwent MRI scans and neuropsychological testing. Many have been retested every two years. Giedd says the initial surprise is that "the brain doesn't change that much in size from age six on." The skull thickens, but the brain is at 90 percent adult size. Its overall breadth is stable during the teen years, "but the components change in size and shape," he adds.

The MRI images show alterations in the wiring among neurons involved in decision making, judgment and impulse control, as well as in the wiring the prefrontal cortex uses to tie brain regions together. Along with other studies, the images show that the prefrontal cortex seems to continue maturing well into the 20s. "It is striking how dynamically the brain changes during the teen years and how long it changes into young adulthood," Giedd says. "Frankly, it surprised us that [ongoing change] lasted so long." Whereas much change occurs during the teen years, adaptation in the prefrontal cortex continues for a number of years afterward.

A Hoax?

Not all neuroscientists or psychologists are ready to accept that the teen brain's innate biology explains reckless behavior, however. Robert Epstein, a psychologist, visiting scholar at the University of California, San Diego, and founder of the Cambridge Center for Behavioral Studies, says he is "infuriated" by the very concept that there is a teen brain that is so different from an adult brain. "There is no such thing. It's a hoax, pushed to some extent by drug companies who are funding research," he asserts.

To bust the myth that routine brain development underlies teenage behavioral problems, Epstein cites the influential book *Blaming the Brain*, by Elliot S. Valenstein (Free Press, 1998), now psychology professor emeritus at the University of Michigan at Ann Arbor. It implies that some neuroscientists come under the influence of drug companies that want to develop the idea that the brain is at fault, easing the way for doctors to prescribe psychoactive drugs. (Note that none of the studies discussed in this article were funded by drug companies.)

> Critics say there is no such thing as a teen brain; the notion is a hoax, encouraged by drug companies.

Perhaps more persuasive is Epstein's observation that studies that implicate a teen brain tend to look only at American adolescents. He says research shows that "teens in other countries and developing nations don't behave or feel like American teens. If you look at multicultural and causation issues, there is no teen brain" that is universally different from adult brains.

American culture has come to define teenage years as tumultuous. "But most teens around the world don't experience any such turmoil," Epstein notes, citing a massive study by anthropologist Alice Schlegel of the University of Arizona and psychologist Herbert Barry III of the University of Pittsburgh. Their book *Adolescence: An Anthropological Inquiry* (Free Press, 1991) examined teens in 186 preindustrial cultures. Schlegel and Barry found that 60 percent of the cultures do not even have a word for adolescence and that most teens spend much of their time with adults, not segregated with only their peers. Antisocial behavior was absent in over half the cultures; where it was found, it was mild.

This is "mind-boggling," Epstein declares, because in America "we define the teen years as storm and stress. To point to the brain as the cause of everything bad is wrong, because envi-

ronment changes the brain. We live in a society where kids are isolated from adults, so they learn from each other." And that, he says, can be a recipe for trouble. Epstein contends that when a society raises adolescents to experience a smooth, swift transition to adulthood, much of the angst assumed to be a given with teens is absent.

Ready or Not

Luna calls Epstein's view "interesting," although she does not agree. Either way, she says, her experiments control for cultural differences because they look at brain function based on emotionally neutral stimuli, not socially relevant behavioral decisions.

As for environmental influence, Luna says the fMRI images suggest that the brain is a vulnerable system and that in an environment with many stresses it is more difficult for adolescents to show self-control as compared with adults. She points out that the structure of the teen brain is "not ready" and that this is a good thing, because it allows the brain to develop more consistently with the particular environment in which it matures. "We're trying to understand the brain-behavior relationship," she adds. "It's not like the teen brain is different from other brains. There is a continuum."

The visual-motor test, she observes, is very difficult, "because the whole brain is wired to look at a visual stimulus." Asking subjects to not look at the light requires frontal regions to communicate with subcortical regions to enforce a planned, endogenous response ("I will not look at the light") that overrules the reflexive, exogenous response ("Look at the light"). "We're asking a teen to do something" that, at most, is only remotely related to risk-taking behavior, she says. "It is a way to look at the basic ability to inhibit a response." Because adolescents have a much harder time performing tasks that require voluntary control, they could be more prone to bad decision making.

Yet when adolescents are in situations with few competing demands, they do indeed behave like adults, Luna says. In preindustrial cultures that is the more likely environment, "so, of course, those teens might not exhibit risk-taking behavior. That doesn't mean their brain is not pruning," she explains. "Or that there isn't something uniquely special about adolescence." M

Adolescents in certain cultures are not racked with the turmoil of American teens, indicating that environment, not inherent brain development, may underlie troubled behavior.

ANTOINE GYORI *Corbis Sygma*

(Further Reading)

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- **fMRI Reveals Alteration of Spatial Working Memory Networks across Adolescence.** A. D. Schweinsburg, B. J. Nagel and S. F. Tapert in *Journal of the International Neuropsychological Society,* Vol. 11, pages 631–644; 2005.
- **Intellectual Ability and Cortical Development in Children and Adolescents.** P. Shaw et al. in *Nature,* Vol. 440, pages 676–679; March 30, 2006.

SEAN MURPHY *Getty Images* (*teen on bike*); CREASOURCE *Corbis* (*teens drinking*); BENJAMIN PORTER *New York Times/Redux* (*teens driving*); MARK PETERSON *Redux* (*teens smoking*); IMAGES USED FOR ILLUSTRATIVE PURPOSES ONLY

Is the Teen Brain Too [RATIONAL?]

With the decision-making areas of their brains still developing, teenagers show poor judgment in risky situations. Thinking less logically may be the answer

By Valerie F. Reyna and Frank Farley

Adolescence is a dangerous time. Some of the most life-threatening risks that people take—drunk driving, binge drinking, smoking, having unprotected sex—are especially common during the teenage years. The following statistics illustrate the enormous toll in human suffering caused by adolescent risk taking:

- Both males and females between the ages of 16 and 20 are at least twice as likely to be in car accidents than drivers between the ages of 20 and 50 are. Auto accidents are the leading cause of death among 15- to 20-year-olds, and 31 percent of young drivers killed in motor vehicle crashes in 2003 had been drinking.
- Three million adolescents contract sexually transmitted diseases every year.
- More than half of all new cases of HIV infection occur in people younger than 25, making AIDS the seventh leading cause of death among 13- to 24-year-olds. Two young people in the U.S. are infected with HIV every hour.
- Forty percent of adult alcoholics report having their first drinking problems between the ages of 15 and 19.
- Evidence of pathological or problem gambling is found in 10 to 14 percent of adolescents, and gambling typically begins by age 12.

In addition to the immediate consequences of risk taking—both for adolescents and for those who suffer from their actions—many behaviors that affect adult health begin and become entrenched during adolescence. So risky activities such as heavy drinking and drug use, which begin as voluntary experimentation, can be perpetuated by addiction. And whereas most teen drinkers, for example, do not progress to alcoholism, virtually all alcoholics started drinking in adolescence.

Preventing risky behavior while it is still a matter of deliberate choice is crucially important—not just for protecting troubled teens but also for society. An obvious answer is early intervention, which is both more successful and less costly than efforts to deal with established addictions later.

Strategies that help to postpone sexual activity, binge drinking and other risky behaviors also have the virtue of giving the forebrain and other neurological structures time to mature. As studies are now showing, the immature adolescent brain may be responsible for much of the risky business that young people engage in.

Over the past two decades, studies using magnetic resonance imaging (MRI) and other imaging techniques have shown that the human brain undergoes major remodeling during childhood and throughout the teen years—anatomical changes that may account for the risk taking, novelty seeking and impulsivity that characterize adolescent behavior. Gray matter in the brain, for example, begins thinning early in childhood—a sequential maturation process that begins at the back of the brain. Not until early adulthood does this wave of gray-matter thinning finally reach the forebrain areas where planning, reasoning and impulse control occur.

This growing evidence that risk taking may be hardwired into the adolescent brain has influenced the way that we and other psychologists now view troubled teenagers and the standard intervention programs aimed at preventing their risky behavior.

Why Programs Fail

Traditional intervention programs emphasize the importance of giving teens information about risks and allowing them the freedom to decide for themselves what to do. These programs encourage teens to trade off potentially deadly risks against often transient benefits and assume that they will see the light: just tell them the risks of HIV infection and unwanted pregnancy, these programs assume, and teens will not engage in unprotected sex.

Such programs are based on a collection of theories of decision making with names like “the behavioral decision framework” and “the theory of reasoned action.” As their names imply, these theories expect that teenagers will weigh risks against benefits and come to the “rational” conclusion about their actions.

Some programs based on these theories have helped reduce risky actions taken by teens. For the most part, however, they have achieved only limited success. In addition to the modest percentage of teens influenced by these intervention efforts, the positive effects of these programs—many of which involve 10 to 20 hours of instruction—typically fade away in a matter of months.

In our view, intervention programs appealing to teen rationality are inherently flawed—and not because teens fail to weigh risks against benefits; as we will see, most teens do so conscientiously. Part of the problem may be that the “unfinished” architecture of their brains hinders adolescents from thinking like adults. Recent studies, for example, show that teens tend to weight benefits more heavily than risks when making decisions. So, after carefully considering the risks and benefits of a situation, the teenage brain all too often comes down on the side of the benefits—and chooses the risky action.

Just as important, traditional intervention programs are flawed because they are based on the notion that teens consider themselves invulnerable—despite evidence now pointing in exactly the opposite direction.

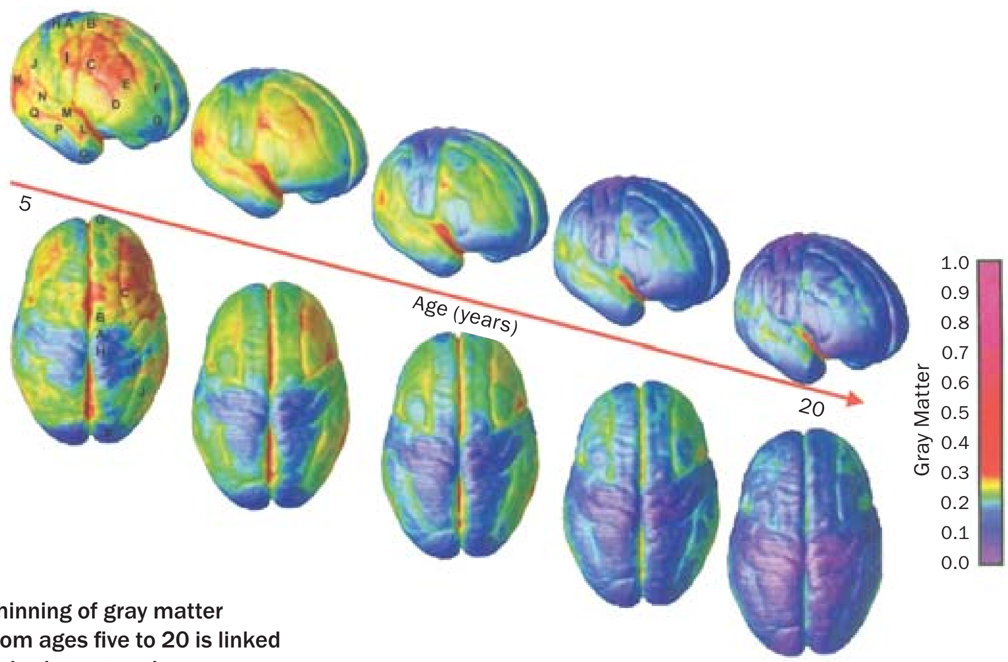
The Invulnerability Myth

For decades, a seductive explanation for risky teen behavior has reigned supreme among both the public and health professionals alike: teens drive too fast, binge drink and have unprotected

(Growing evidence indicates that risk taking **may be hardwired** into the adolescent brain.)

Less Is More in Brain Development

To trace the development of the human brain, researchers at the National Institute of Mental Health recruited 13 children to undergo magnetic resonance imaging (MRI) brain scans every two years for eight to 10 years. Because MRI scanning reveals the volume of gray matter (composed mainly of nerve cell bodies) in the brain's cortex, the researchers were able to produce a time-lapse sequence of brain development. Shown here are two views—right lateral and top—of how gray matter matures over the cortical surface from the ages of five to 20. The color bar on the right represents the volume of gray matter in units. The imaging study reveals progressive "thinning" of gray matter in a wave that starts at the back of the brain and progresses to the front. Those regions that mature last—not until early adulthood—are associated with higher-order functions such as planning, reasoning and impulse control. *—V.F.R. and F.F.*



Thinning of gray matter from ages five to 20 is linked to brain maturation.

sex because they feel they are invulnerable. They must therefore be underestimating their risks, or otherwise they would not take such chances. But studies uniformly dispute the widespread belief that adolescents consider themselves more invulnerable than adults (who, it turns out, are more likely to consider *themselves* invulnerable when compared with teens). And when it comes to risk, studies over the past five years show that teens actually tend to *overestimate* rather than underestimate the true risks of potential actions.

For example, a 2002 study by Susan Millstein and Bonnie Halpern-Felsher of the University of California, San Francisco, found that adolescents were more likely than adults to overestimate risks for every outcome that could be evaluated, including low-probability events (earthquakes and HIV transmission from unprotected sex, for instance) as well as higher-probability events (acquiring sexually transmitted diseases such as gonorrhea and chlamydia).

Another study, published in 2000 by Baruch Fischhoff of Carnegie Mellon University and his colleagues, reported on risk predictions assessed in a nationally representative sample of 3,544 adolescents from the 1997 National Longitudinal Study of Youth. Adolescents' risk estimates for "die from any cause—crime, illness, accident and so on" in the next year or by age 20 were much higher than shown by statistical data. Recent data collected by one of us (Reyna) underline these differences between perceived and ac-

The perceived benefits of an action tend to **outweigh and offset** its risks.

tual risks when it comes to sexually transmitted infections.

Interestingly, teens' overestimation of risk appears to decline after early adolescence, and evidence suggests that experience may be responsible: engaging in risk taking without incurring immediate consequences may encourage complacency.

If adolescents often overestimate risks and do not think of themselves as being invulnerable, then why do they engage in risky behaviors? A number of studies indicate that when adolescents are mulling over risk taking, the perceived benefits of the action tend to outweigh and offset the perceived risks. For example, in a 2002 study of young (fifth to ninth grade) adolescents, Julie H. Goldberg of the University of Illinois at Chicago and her colleagues at the University of California, San Francisco, found that the perceived benefits of alcohol outweighed perceived risks in predicting the students' drinking behavior six months later.

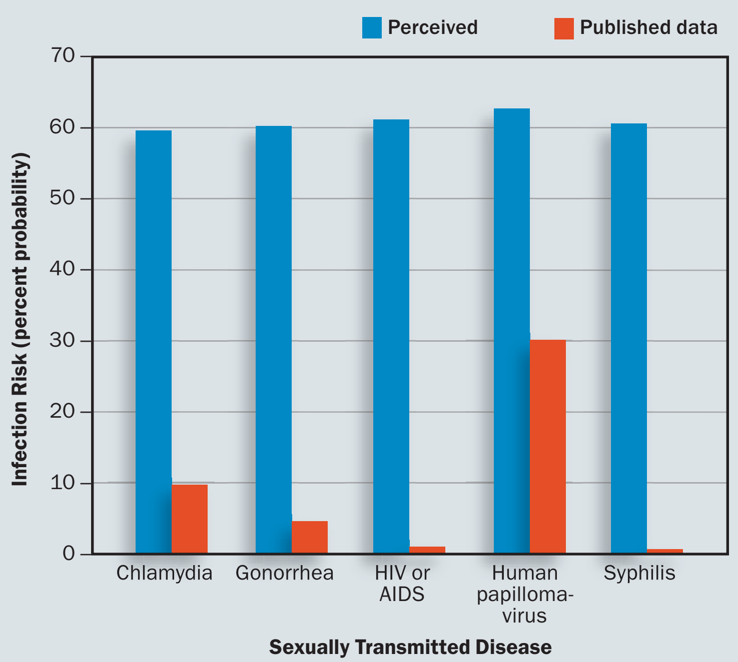
It now becomes clearer why traditional intervention programs fail to help many teenagers. Although the programs stress the importance of accurate risk perception, young people already feel vulnerable and overestimate their risks. And programs fail to alert teens about the allure of benefits, even though the teenage mind emphasizes the benefits of a potentially dangerous situation over its risks.

Some teens have certainly been "scared straight" by traditional intervention programs. But for the most part, such programs have not done much to deter risky behavior—and, even worse, they may actually be encouraging it.

Consider the adolescent who puts his odds of becoming infected with HIV through a single act of unprotected sex at 50–50 … and then learns through his intervention program that his true risk is one in 500 at most. The program's emphasis on inundating teens with risk information could well backfire, making them more rather than less likely to have unprotected sex or engage in other risky actions.

To improve the success of intervention efforts, we are testing a strategy fundamentally different from the one that traditional programs are based on: rather than asking teens to rationally balance risks and benefits, we are training them to think less logically and more intuitively—the way mature adults do, in other words.

Exaggerating Risks



When 254 students in the ninth to 12th grades were asked about the likelihood that a sexually active teenage girl would contract a sexually transmitted disease, they assumed that her risk of infection was much higher than it actually is.

SOURCE: "RISK AND RATIONALITY IN ADOLESCENT DECISION MAKING: IMPLICATIONS FOR THEORY, PRACTICE, AND PUBLIC POLICY," BY V. F. REYNA AND F. FARLEY, IN *PSYCHOLOGICAL SCIENCE IN THE PUBLIC INTEREST*, VOL. 7, NO. 1; SEPTEMBER 2006

Accentuate the Intuitive

This new strategy is based on a theory jointly proposed about 20 years ago by one of us (Reyna) and Charles Brainerd, now at Cornell University. Called fuzzy-trace theory, it originally was regarded as quite radical. Today, however, it can be described as an "establishment" theory of cognitive development because research has confirmed so many of its surprising predictions. It offers an explanation for the evolution of behaviors and memories from childhood, through adolescence and on to adulthood based on changes that occur in the way we reason. A decade ago fuzzy-trace theory predicted and discovered the counterintuitive finding that some false memories are more stable over time than true memories, among other novel findings.

Fuzzy trace is a so-called dual-processes the-

One Girl's Intervention Experience

The following is a conversation with a 15-year-old girl who had previously had an unintended pregnancy and now participates in the intuitive, gist-enhanced intervention program that we devised. *—V.F.R. and F.F.*

Q: Why do you feel you made ill-advised decisions in the past?

A: It was partly because of the friends I hung out with and also because we assumed that doing what we did—having sex, not bothering with condoms—wasn't bad.

Q: How has the program affected your responses to potentially risky situations?

A: I think specifically I learned how important it is to use a condom, and the program really opened my eyes to how common STDs [sexually transmitted diseases] are and how cautious I need to be to avoid them.

Q: Has the intervention made you feel more in control of your life?

A: Yes, because in talking about all the different ways to say "no," I've actually used them, which makes me feel much more comfortable.

And I feel confident. I don't feel stupid by saying "no." And even if people think I'm stupid, that's their problem.

ory positing that people rely on two quite different ways of reasoning to reach conclusions about situations confronting them. The first way is a deliberative, analytical approach that relies on details, such as those collected during rote exercises and fact memorization. This verbatim style of reasoning involves the kind of computational processing assumed by risk-intervention programs, when risks are traded off precisely against rewards. Far from being analytical, the second, or "fuzzy," style of reasoning occurs unconsciously and above all involves intuition, allowing people to penetrate quickly to the gist, or bottom line, of a situation. (The word "trace" in fuzzy-trace theory refers to the mental pictures, or traces, that collectively constitute memory.)

Fuzzy-trace theory's different modes of reasoning—verbatim and gist—are by no means mutually exclusive and can actually operate in the same person at the same time. But each predominates at different stages of life in normal human development.

Legendary developmental psychologist Jean Piaget contended that we start off as intuitive children who become analytical adults. Fuzzy-trace theory reverses things, proposing instead that the verbatim mode of reasoning reigns during childhood and adolescence. Then, with maturity, gist thinking takes over as we make decisions that disregard distracting details and instead are filtered through our experience, emotions, worldview, education and other factors.

The intuitive, gist-based approach to decision making tends to yield a "simple" answer—a black-and-white conclusion of good or bad, safe or hazardous, for example. Yet gist appears to be the more advanced form of reasoning, because the tendency to base decisions on gist increases with age, experience and expertise, as shown by research with children and adults.

Fuzzy-Trace Theory and Risk

When it comes to handling risks, fuzzy-trace theory predicts that mature decision makers will not deliberate about the degree of risk and the magnitude of benefits if a nontrivial chance of a catastrophic or health-compromising outcome exists. In contrast, the verbatim-based, analytical approach of adolescents faced with a risky situation would be expected to take longer. And indeed, studies comparing the reaction times in milliseconds for adults and adolescents to questions such as "Is it a good idea to set your hair on fire?" and "Is it a good idea to drink a bottle of Drano?" show that adults respond faster than teens.

In recent years, colleagues have suggested that fuzzy-trace theory could be applied to the vexing problem of adolescent risk taking. We have taken up the challenge, and our research suggests that adding a gist-based component to intervention programs serves a useful purpose. We believe that emphasizing intuitive rather than "logical" reasoning in potentially risky situations could help many—but not all—adolescents avoid engaging in risky behavior.

We propose that there are two kinds of teens who make similarly risky choices but do so through very different routes. We have dubbed

(The Authors)

VALERIE F. REYNA and FRANK FARLEY have studied risk for a quarter of a century. Reyna is co-director of the Center for Behavioral Economics and Decision Research and professor of human development and of psychology at Cornell University. Farley is L. H. Carnell Professor at Temple University and former president of the American Psychological Association.

these two groups the risky deliberators and the risky reactors.

The risky deliberators encompass the vast majority of teenagers—those who are in the normal developmental stage of adolescence. Before doing something potentially dangerous, risky deliberators rationally trade off risks against benefits, just as risk-intervention programs encourage them to do. And all too often, the risky deliberators come to a conclusion that, for them, is entirely logical: they conclude that the benefits of a risky action outweigh its risks—and intentionally go ahead and do it.

Consider the extreme example of Russian roulette, which was featured so prominently in the movie *The Deer Hunter*. Nick, played by Christopher Walken, has made a considerable amount of money gambling on Russian roulette. We last see him in a gambling den in Saigon sitting opposite his old friend Michael (Robert De Niro) and holding a gun to his head.

Nick clearly was mentally unstable, traumatized by his ordeal in the Vietnam War and addicted to heroin. But for risky deliberators and for the standard intervention programs aimed at helping them (and for economists of a certain stripe), the decision to play Russian roulette could be considered rational if the payoff in dollars were large enough. After all, the benefit could be a fortune that lasts a lifetime … and the risk of dying is only one in six.

The young risky deliberator has relied on verbatim reasoning that is age-appropriate and logical but that could result in a tragic outcome. Most adults, on the other hand, will look at this scenario—money to win and a gun with a single bullet in the chamber—and ask, "Are you crazy? No amount of money you could offer would get me to put that gun to my head. This is not about the number of dollars or the number of bullets—we're talking about a significant risk of dying here." Adults, of course, are using gist-based thinking to cut quickly through the distractions, grasp the bottom-line meaning and arrive at a simple answer: absolutely not.

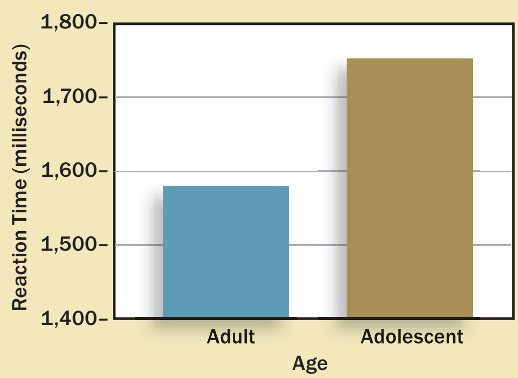
Impulsive Reactors

Risky reactors, on the other hand, are not thinking deeply or analytically. Instead they act impulsively because of some temptation in their environment. Risky reactors do not *intend* to do something dangerous. But for any number of reasons—including peer-group pressure or the excitement of the moment—they are pulled into risky situations, often against their better judgment.

Fortunately, most risky reactors grow out of their impulsiveness once they reach adulthood. But in the meantime, efforts to influence cognitive development by encouraging intuitive thinking probably will not help these teens, who are responders rather than thinkers. Instead measures for protecting unintentional risk takers should focus on adult supervision or monitoring to minimize opportunities for reacting to temptation.

Risky deliberators—the much larger group of at-risk adolescents—stand a far better chance of benefiting from exposure to intuitive, gist-based thinking. These teens do engage in reasoning—

Thinking about the Unthinkable



In studies measuring their reaction time, teens deliberate much longer than adults before answering "no" to questions such as "Is it a good idea to drink a bottle of Drano?"

DANNY WILCOX FRAZIER *Redux* (*photograph*); SOURCE: "RISK AND RATIONALITY IN ADOLESCENT DECISION MAKING: IMPLICATIONS FOR THEORY, PRACTICE, AND PUBLIC POLICY," BY V. F. REYNA AND F. FARLEY, IN *PSYCHOLOGICAL SCIENCE IN THE PUBLIC INTEREST*, VOL. 7, NO. 1; SEPTEMBER 2006 (*graph*)

flawed though the outcomes may be—so we may be able to influence *how* they reason. To that end, we are now testing a gist-enhanced intervention program in a clinical trial involving more than 800 adolescents. Results should be available by the end of the year [*see box on page 65 for comments of one at-risk teenager who seems to be benefiting from this gist-based intervention effort*].

We are optimistic that gist-based thinking will one day be widely incorporated into risk-intervention programs, where it could help young people pass unscathed through their dangerous teenage years. For now, we offer the following empirically supported recommendations for guiding adolescents and helping them avoid taking unhealthy risks:

- Offer risky deliberators well-reasoned arguments for resisting risky behaviors as well as factual information about social norms ("The notion that everyone your age is having sex just isn't true"). Focus on reducing the perceived benefits of risky behaviors—and on increasing the perceived benefits of safer, alternative behaviors.
- Teens may not grasp the concept of "harmful consequences" because of their lack of relevant experience (which can also make them prone to repeated risk taking, if they have so far managed to "dodge the bullets" of negative consequences). Help them to understand the meaning of risk-related truths (the fact that HIV is not treatable with antibiotics means that AIDS cannot be cured) and to derive the gist, or bottom line, of messages that will endure in memory longer than verbatim facts.
- Reduce risk by retaining or implementing higher drinking ages, eliminating or lowering the number of peers who can accompany young drivers, and reducing exposure to potentially addictive substances (rather than trying to teach minors to drink responsibly, for example).
- Monitor and supervise younger adolescents rather than relying on them to make reasoned choices or to learn from the school of hard knocks; remove opportunities for them to engage in risky behavior.
- Encourage teens to develop positive gists or images of healthy behaviors and negative images of unhealthy behaviors by exposing them to films, novels, serial dramas or other emotionally evocative media.
- Identify and encourage teenagers to adopt so-called self-binding strategies ("I will not attend unsupervised parties") and help them to practice recognizing cues that signal danger before it is too late to act ("I will not ride with a drinking driver"). M

Should the number of bullets matter in deciding whether to play Russian roulette? Making a rational decision may require not thinking analytically.

RON ROVTAR *Getty Images*

(Further Reading)

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PETER DAZELEY *Getty Images*

We blame teen turmoil on immature brains. But did the brains cause the turmoil, or did the turmoil shape the brains?

The Myth of the Teen Brain

By Robert Epstein

It's not only in newspaper headlines—it's even on magazine covers. *TIME, U.S. News & World Report* and even *Scientific American Mind* have all run cover stories proclaiming that an incompletely developed brain accounts for the emotional problems and irresponsible behavior of teenagers. The assertion is driven by various studies of brain activity and anatomy in teens. Imaging studies sometimes show, for example, that teens and adults use their brains somewhat differently when performing certain tasks.

As a longtime researcher in psychology and a sometime teacher of courses on research methods and statistics, I have become increasingly concerned about how such studies are being interpreted. Although imaging technology has shed interesting new light on brain activity, it is dangerous to presume that snapshots of activity in certain regions of the brain necessarily provide useful information about the causes of thought, feeling and behavior.

If the “teen brain” were a universal phenomenon, we would find teen turmoil around the world.

Automatically assuming that the brain causes behavior is problematic because we know that an individual’s genes and environmental history—and even his or her own behavior—mold the brain over time. There is clear evidence that any unique features that may exist in the brains of teens—to the limited extent that such features exist—are the *result* of social influences rather than the *cause* of teen turmoil. As you will see, a careful look at relevant data shows that the teen brain we read about in the headlines—the immature brain that supposedly causes teen problems—is nothing more than a myth.

Cultural Considerations

The teen brain fits conveniently into a larger myth, namely, that teens are inherently incompetent and irresponsible. Psychologist G. Stanley Hall launched this myth in 1904 with the publication of his landmark two-volume book *Adolescence*. Hall was misled both by the turmoil of his times and by a popular theory from biology that later proved faulty. He witnessed an exploding industrial revolution and massive immigration that put hundreds of thousands of young people onto the streets of America’s burgeoning cities. Hall never looked beyond those streets in formulating his theories about teens, in part because he believed in “recapitulation”—a theory from biology that asserted that individual development (ontogeny) mimicked evolutionary development (phylogeny). To Hall, adolescence was the necessary and inevitable reenactment of a “savage, pigmoid” stage of human evolution. By the 1930s recapitulation theory was completely discredited in biology, but some psychologists and the general public never got the message. Many still believe, consistent with Hall’s assertion, that teen turmoil is an *inevitable* part of human development.

Today teens in the U.S. and some other Westernized nations do display some signs of distress. The peak age for arrest in the U.S. for most crimes has long been 18; for some crimes, such as arson, the peak comes much earlier. On average, American parents and teens tend to be in conflict with one another 20 times a month—an extremely high figure indicative of great pain on both sides. An extensive study conducted in 2004 suggests that 18 is the peak age for depression among people 18 and older in this country. Drug use by teens, both legal and illegal, is clearly a problem here, and suicide is the third leading cause of death among U.S. teens. Prompted by a rash of deadly school shootings over the past decade, many American high schools now resemble prisons, with guards, metal detectors and video monitoring systems, and the high school dropout rate is nearly 50 percent among minorities in large U.S. cities.

But are such problems truly inevitable? If the turmoil-generating “teen brain” were a universal developmental phenomenon, we would presumably find turmoil of this kind around the world. Do we?

In 1991 anthropologist Alice Schlegel of the University of Arizona and Herbert Barry III, a psychologist at the University of Pittsburgh, reviewed research on teens in 186 preindustrial societies. Among the important conclusions they drew about these societies: about 60 percent had no word for “adolescence,” teens spent almost all their time with adults, teens showed almost no signs of psychopathology, and antisocial be-

FAST FACTS
Troubled Teens

1» Various imaging studies of brain activity find that teens and adults use their brains somewhat differently when performing certain tasks. These studies are said to support the idea that an immature “teen brain” accounts for teen mood and behavior problems.

2» But, the author argues, snapshots of brain activity do not necessarily identify the *causes* of such problems. Culture, nutrition and even the teen’s own behavior all affect brain development. A variety of research in several fields suggests that teen turmoil is caused by cultural factors, not by a faulty brain.

3» Anthropological research reveals that teens in many cultures experience no turmoil whatsoever and that teen problems begin to appear only after Western schooling, movies and television are introduced.

4» Teens have the potential to perform in exemplary ways, the author says, but we hold them back by infantilizing them and trapping them in the frivolous world of teen culture.

havior in young males was completely absent in more than half these cultures and extremely mild in cultures in which it did occur.

Even more significant, a series of long-term studies set in motion in the 1980s by anthropologists Beatrice Whiting and John Whiting of Harvard University suggests that teen trouble begins to appear in other cultures soon after the introduction of certain Western influences, especially Western-style schooling, television programs and movies. Delinquency was not an issue among the Inuit people of Victoria Island, Canada, for example, until TV arrived in 1980. By 1988 the Inuit had created their first permanent police station to try to cope with the new problem.

Consistent with these modern observations, many historians note that through most of recorded human history the teen years were a relatively peaceful time of transition to adulthood. Teens were not trying to break away from adults; rather they were learning to *become* adults. Some historians, such as Hugh Cunningham of the University of Kent in England and Marc Kleijwegt of the University of Wisconsin–Madison, author of *Ancient Youth: The Ambiguity of Youth and the Absence of Adolescence in Greco-Roman Society* (J. C. Gieben, 1991), suggest that the tumultuous period we call adolescence is a very recent phenomenon—not much more than a century old.

My own recent research, viewed in combination with many other studies from anthropology, psychology, sociology, history and other disciplines, suggests the turmoil we see among teens in the U.S. is the result of what I call the "artificial extension of childhood" past the onset of puberty. Over the past century, we have increasingly infantilized our young, treating older and older people as children while also isolating them from adults and passing laws to restrict their behavior [*see box on next page*]. Surveys I have conducted show that teens in the U.S. are subjected to more than 10 times as many restrictions as are mainstream adults, twice as many restrictions as active-duty U.S. Marines, and even twice as many restrictions as incarcerated felons. And research I conducted with Diane Dumas as part of her dissertation research at the California School of Professional Psychology shows a positive correlation between the extent to which teens are infantilized and the extent to which they display signs of psychopathology.

In many Western cultures, teens socialize almost exclusively with other teens.

CATHERINE LEDNER *Getty Images*

The headlines notwithstanding, there is no question that teen turmoil is *not* inevitable. It is a creation of modern culture, pure and simple—and so, it would appear, is the brain of the troubled teen.

Dissecting Brain Studies

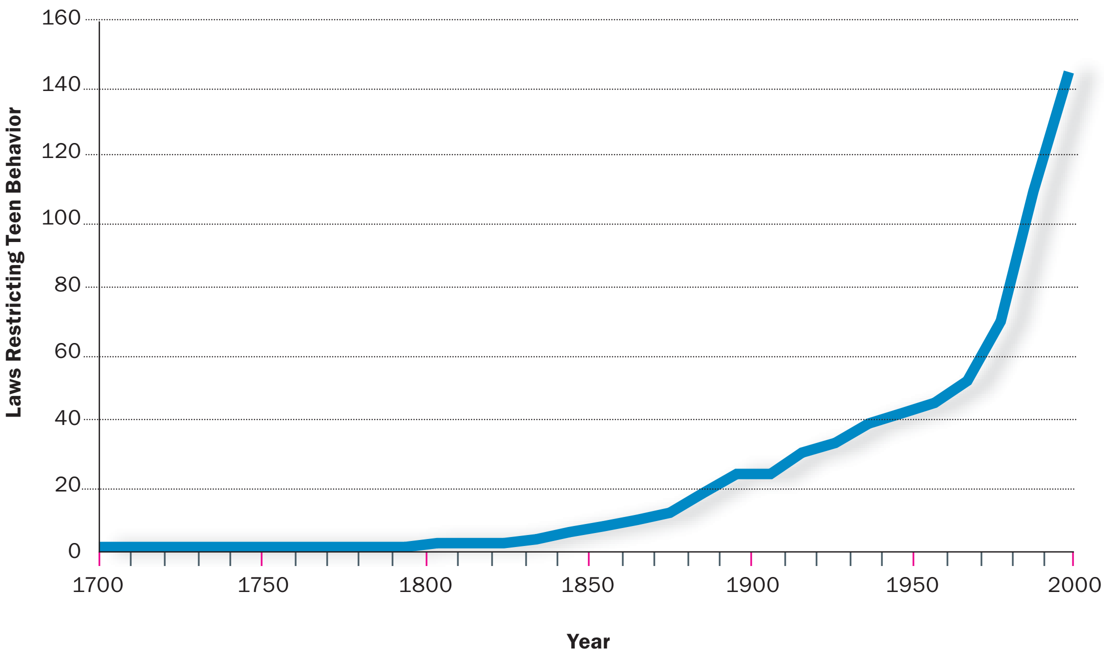
A variety of recent research—most of it conducted using magnetic resonance imaging (MRI) technology—is said to show the existence of a teen brain. Studies by Beatriz Luna of the Laboratory of Neurocognitive Development at the University of Pittsburgh, for example, are said to show that teens use prefrontal cortical resources differently than adults do. Susan F. Tapert of the University of California, San Diego, found that for certain memory tasks, teens use smaller areas of the cortex than adults do. An electroencephalogram (EEG) study by Irwin Feinberg and his colleagues at the University of California, Davis, shows that delta-wave activity during sleep declines in the early teen years. Jay N. Giedd of the Child Psychiatry Branch at the National Institute of Mental Health and other researchers suggest that the decline in delta-wave activity might be related to synaptic pruning—a reduction in the number of interconnections among neurons.

This work seems to support the idea of the teen brain we see in the headlines until we realize two things. First, most of the brain changes that are observed during the teen years lie on a continuum of changes that take place over much of our lives. For example, a 1993 study by Jésus Pujol and his colleagues at the Autonomous University of Barcelona looked at changes in the corpus callosum—a massive structure that connects the two sides of the brain—over a two-year period with individuals between 11 and 61 years old. They found that although the rate of growth declined as people aged, this structure still grew by about 4 percent each year in people in their 40s (compared with a growth rate of 29 percent in their youngest subjects). Other studies, conducted by researchers such as Elizabeth Sowell of the University of California, Los Angeles, show that gray matter in the brain continues to disappear from childhood well into adulthood.

Second, I have not been able to find even a single study that establishes a *causal* relation between the properties of the brain being examined and the problems we see in teens. By their very nature, imaging studies are correlational,

Rebels with a Cause

Laws restricting the behavior of young people (under age 18) have grown rapidly in the past century, according to a survey by the author. He found that U.S. teens have 10 times as many restrictions as adults, twice as many as active-duty U.S. Marines and twice as many as incarcerated felons.



SOURCE: *THE CASE AGAINST ADOLESCENCE*, BY ROBERT EPSTEIN (QUILL DRIVER BOOKS, 2007)

Studies of intelligence, perception and memory show that teens are in many ways superior to adults.

ERIK DREYER Getty Images

Young people have extraordinary potential that is often not expressed because teens are infantilized and isolated from adults.

showing simply that activity in the brain is associated with certain behaviors or emotions. As we learn in elementary statistics courses, correlation does not even imply causation. In that sense, no imaging study could possibly identify the brain as a causal agent, no matter what areas of the brain were being observed.

Is it ever legitimate to say that human behavior is caused by brain anatomy or activity? In his 1998 book *Blaming the Brain,* Elliot S. Valenstein, now psychology professor emeritus at the University of Michigan at Ann Arbor, deftly points out that we make a serious error of logic when we blame almost any behavior on the brain—especially when drawing conclusions from brain-scanning studies. Without doubt, all behavior and emotion must somehow be reflected (or "encoded") in brain structure and activity; if someone is impulsive or lethargic or depressed, for example, his or her brain must be wired to reflect those behaviors. But that wiring (speaking loosely) is not necessarily the cause of that behavior or emotion.

Considerable research shows that a person's emotions and behaviors continuously change brain anatomy and physiology. Stress creates hypersensitivity in dopamine-producing neurons that persists even after they are removed from the brain. Enriched environments produce more neuronal connections. For that matter, meditation, diet, exercise, studying and virtually all other activities alter the brain, and a new study shows that smoking produces brain changes similar to those produced in animals given heroin, cocaine or other addictive drugs. So if teens are in turmoil, we will necessarily find some corresponding chemical, electrical or anatomical properties in the brain. But did the brain cause the turmoil, or did the turmoil alter the brain? Or did some other factors—such as the way our culture treats its teens—cause both the turmoil and the corresponding brain properties?

(The Author)

ROBERT EPSTEIN is a contributing editor for *Scientific American Mind* and the former editor in chief of *Psychology Today.* He received his Ph.D. in psychology from Harvard University and is a longtime researcher and professor. His latest book is called *The Case against Adolescence: Rediscovering the Adult in Every Teen* (Quill Driver Books, 2007). More information is at www.thecaseagainstadolescence.com

Elected achievers: Sam Juhl, now 19, mayor of Roland, Iowa (*right*), and Michael Sessions, now 19, mayor of Hillsdale, Mich. (*below*).

ANDREW RULLESTAD *The Ames Tribune/AP Photo* (*top*); BILL PUGLIANO *Getty Images News* (*bottom*)

Unfortunately, news reports—and even the researchers themselves—often get carried away when interpreting brain studies. For instance, a 2004 study conducted by James Bjork and his colleagues at the National Institute on Alcohol Abuse and Alcoholism, at Stanford University and at the Catholic University of America was said in various media reports to have identified the biological roots of teen laziness. In the actual study, 12 young people (ages 12 to 17) and 12 somewhat older people (ages 22 to 28) were monitored with an MRI device while performing a simple task that could earn them money. They were told to press a button after a short anticipation period (about two seconds) following the brief display of a symbol on a small mirror in front of their eyes. Some symbols indicated that pressing the button would earn money, whereas others indicated that failing to respond would cost money. After the anticipation period, subjects had 0.25 second to react, after which time information was displayed to let them know whether they had won or lost.

Areas of the brain that are believed to be involved in motivation were scanned during this session. Teens and adults were found to perform equally well on the task, and brain activity differed somewhat in the two groups—at least during the anticipation period and when $5 (the maximum amount that could be earned) was on the line. Specifically, on those high-payment trials the average activity of neurons in the right nucleus accumbens—but not in other areas that were being monitored—was higher for adults than for teens. Because brain activity in the two groups did not differ in other brain areas or under other payment conditions, the researchers drew a very modest conclusion in their article: "These data indicate qualitative similarities overall in the brain regions recruited by incentive processing in healthy adolescents and adults."

But according to the Long Island, N.Y., newspaper *Newsday,* this study identified a "biological reason for teen laziness." Even more disturbing, lead author James Bjork said that his study "tells us that teenagers love stuff, but aren't as willing to get off the couch to get it as adults are."

In fact, the study supports neither statement. If you truly wanted to know something about the brains of lazy teens, at the very least you would have to have some lazy teens in your study. None were identified as such in the Bjork study. Then you would have to compare the brains of those teens with the brains of industrious teens, as well as with the brains of both lazy and industrious adults. Most likely, you would then end up finding out how, on average, the brains in these four groups differed from one another. But even this type of analysis would not allow you to conclude that some teens are lazy "because" they have faulty brains. To find out why certain teens or certain adults are lazy (and, perforce, why they have brains that reflect their lazy tendencies), you would still have to look at genetic and environmental factors. A brain-scanning study can shed no light.

Valenstein blames the pharmaceutical industry for setting the stage for overinterpreting the results of brain studies such as Bjork's. The drug companies have a strong incentive to convince public policymakers, researchers, media professionals and the general public that faulty brains underlie all our problems—and, of course, that pharmaceuticals can fix those problems. Researchers, in turn, have a strong incentive to convince the public and various funding agencies that their research helps to "explain" important social phenomena.

(When we treat teens like adults, they almost immediately **rise to the challenge**.)

The Truth about Teens

If teen chaos is not inevitable, and if such difficulty cannot legitimately be blamed on a faulty brain, just what is the truth about teens? The truth is that they are extraordinarily competent, even if they do not normally express that competence. Research I conducted with Dumas shows, for example, that teens are as competent or virtually as competent as adults across a wide range of adult abilities. And long-standing studies of intelligence, perceptual abilities and memory function show that teens are in many instances far superior to adults.

Visual acuity, for example, peaks around the time of puberty. "Incidental memory"—the kind of memory that occurs automatically, without any mnemonic effort, peaks at about age 12 and declines through life. By the time we are in our 60s, we remember relatively little "incidentally," which is one reason many older people have trouble mastering new technologies. In the 1940s pioneering intelligence researchers J. C. Raven and David Wechsler, relying on radically different kinds of intelligence tests, each showed that raw scores on intelligence tests peak between ages 13 and 15 and decline after that throughout life. Although verbal expertise and some forms of judgment can remain strong throughout life, the extraordinary cognitive abilities of teens, and especially their ability to learn new things rapidly, are beyond question. And whereas brain size is not necessarily a good indication of processing ability, it is notable that recent scanning data collected by Eric Courchesne and his colleagues at the University of California, San Diego, show that brain volume peaks at about age 14. By the time we are 70 years old, our brain has shrunk to the size it had been when we were about three.

Findings of this kind make ample sense when you think about teenagers from an evolutionary perspective. Mammals bear their young shortly after puberty, and until very recently so have members of our species, *Homo sapiens*. No matter how they appear or perform, teens *must* be incredibly capable, or it is doubtful the human race could even exist.

Today, with teens trapped in the frivolous world of peer culture, they learn virtually everything they know from one another rather than from the people they are about to become. Isolated from adults and wrongly treated like children, it is no wonder that some teens behave, by adult standards, recklessly or irresponsibly. Almost without exception, the reckless and irresponsible behavior we see is the teen's way of declaring his or her adulthood or, through pregnancy or the commission of serious crime, of instantly *becoming* an adult under the law. Fortunately, we also know from extensive research both in the U.S. and elsewhere that when we treat teens like adults, they almost immediately rise to the challenge.

We need to replace the myth of the immature teen brain with a frank look at capable and savvy teens in history, at teens in other cultures and at the truly extraordinary potential of our own young people today. **M**

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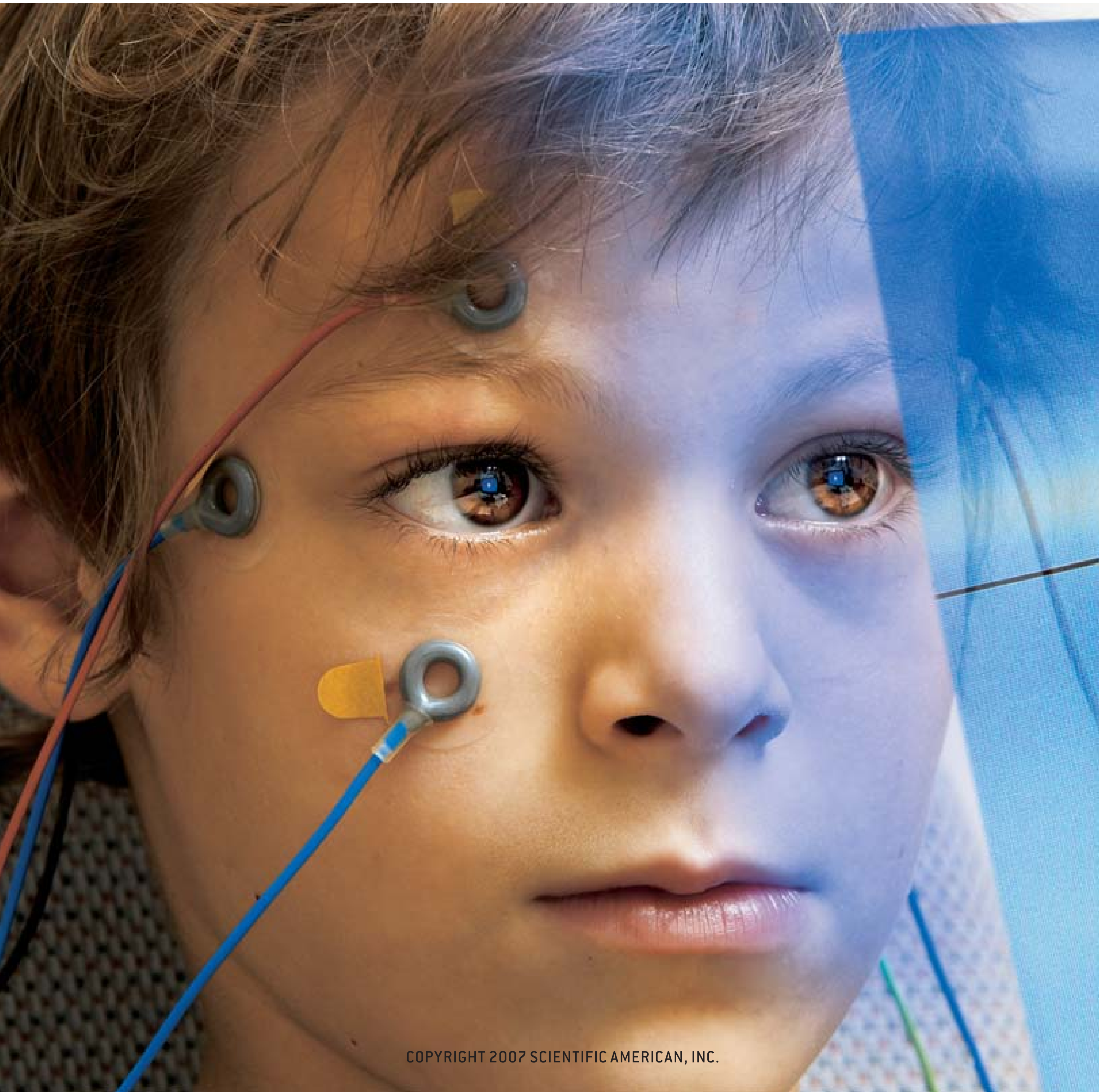
TRAIN YOUR BRAIN

MENTAL EXERCISES WITH NEUROFEEDBACK MAY EASE SYMPTOMS OF ATTENTION-DEFICIT DISORDER, EPILEPSY AND DEPRESSION—AND EVEN BOOST COGNITION IN HEALTHY BRAINS

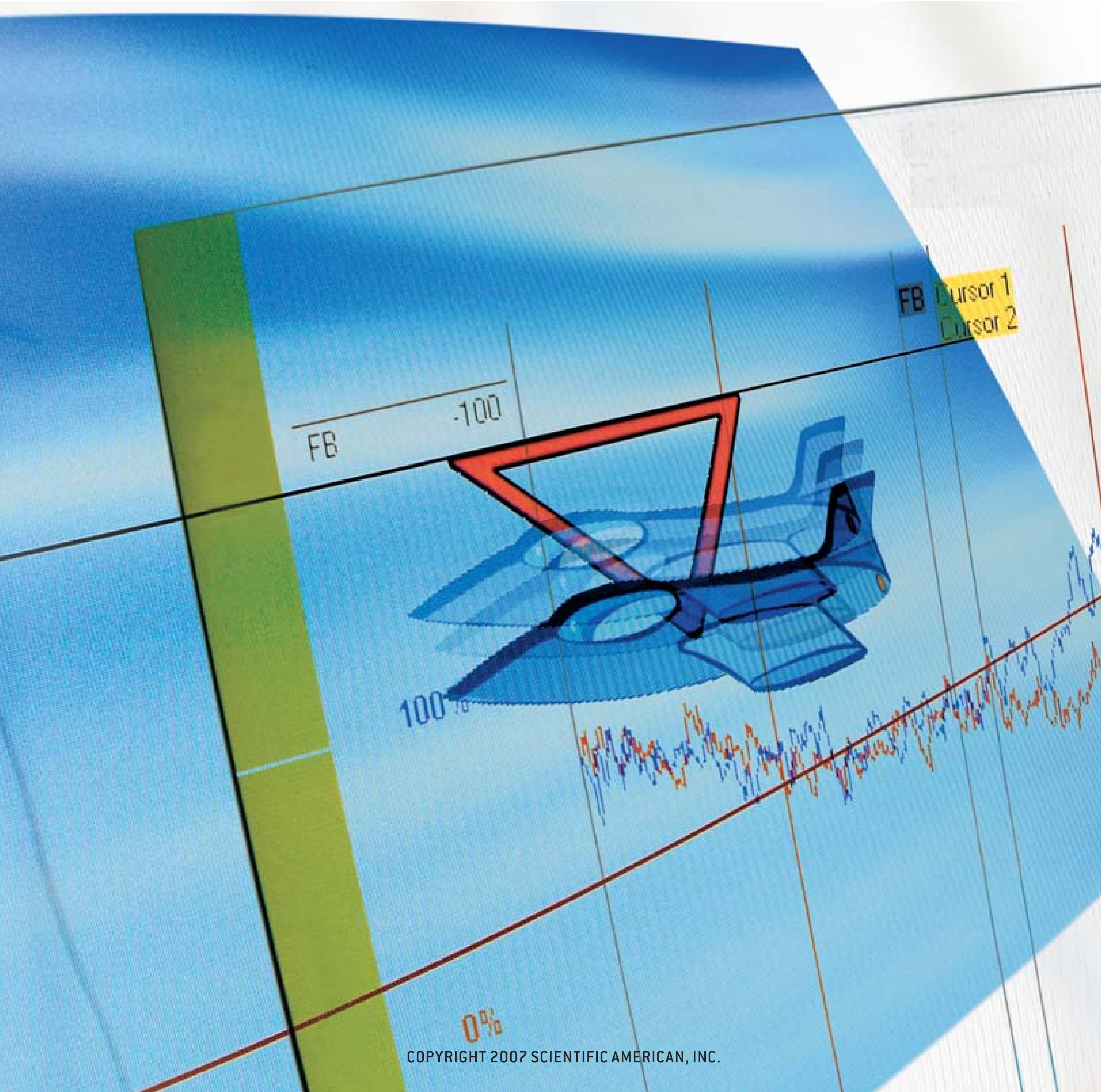
BY ULRICH KRAFT

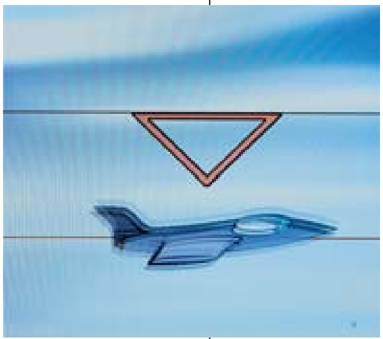


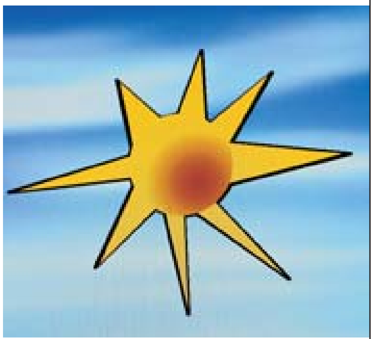
At first the computer game looks awfully easy for an eight-year-old—like something out of the Stone Age of arcades in the 1980s. A red triangle "arrow" appears on the monitor's blue screen, and then the nose of a cartoon airplane glides into view from the left. If the arrow points upward, Ben must make the plane climb. When he succeeds, a spiky yellow sun beams.

A second glance shows that all is not as it seems. For one thing, Ben has no joystick. Instead several electrodes glued to the boy's face and to the skin under his hair let him pilot the plane by thought alone.

Ben is participating in an experiment. The point is to take advantage of neurofeedback—a training tool based on electroencephalography (EEG), the measurement of changes in electrical potential that accompany any brain activity.







Neurofeedback training uses an arrow to tell Ben, a participant in an experiment, where to mentally steer an airplane. If he can do it, the "sun" will shine.

MANFRED ZENTSCH *Gehirn & Geist (preceding pages, this page and opposite page)*

Electrodes conduct the brain signals, which are then processed by a computer program and fed into the game. The plane's motion thus reveals to Ben what just happened in his head. "Through the feedback the children are supposed to learn to deliberately control certain parameters of their brain activity," explains psychologist Ulrike Leins of the University Hospital for Psychiatry and Psychotherapy at the University of Tuebingen in Germany.

Such "mind reading" offers many possible applications. It has, for instance, enabled "locked-in" patients—who cannot speak or gesture—to communicate with caregivers. By controlling their brain waves, the patients manipulate letters and words on a computer screen. Practice with neurofeedback may also benefit those who suffer from epilepsy, attention deficits, depression and other debilitating mental disorders. The experimental therapy, also called EEG biofeedback, may even help rev up healthy brains, improving cognitive performance.

From Bio to Neuro

The technique is a high-tech twist on biofeedback—a method long used to treat stress-related disorders. In biofeedback, people see or hear physiological measurements that can indicate stress, such as increases in blood pressure, heart rate or muscle tension. Receiving such information from monitoring devices makes normally undetectable body functions accessible for conscious regulation. A person can realize from listening to his racing pulse, for example, that he is under strain and then learn to bring his heart rate down purposely.

The first clues that brain waves could be al-

There is no magic formula for learning how to harness one's brain waves.

tered intentionally came nearly four decades ago. In the late 1960s sleep researcher M. Barry Sterman learned something interesting while tracking the EEGs of cats. He found a previously unknown pattern of brain waves with frequencies between 12 and 15 hertz (Hz), or cycles per second, in a part of the brain called the sensorimotor cortex. Sterman, now professor emeritus at the University of California, Los Angeles, dubbed this pattern the sensorimotor rhythm, or SMR. SMR was always present, he learned, in relaxed and awake felines. When he rewarded the animals at those moments with snacks, they began to produce stronger SMRs. Through this conditioning experiment, Sterman demonstrated that it is possible to change one's own brain waves deliberately.

The researcher might well not have followed up on this discovery. But at roughly the same time, he received a request from the U.S. Air Force, which wanted him to test the potential cognitive effects of exposure to monomethylhydrazine, a substance used in some rocket fuels and known to cause seizures. Sterman injected the chemical into cats. About an hour afterward, most of them suffered a seizure. In a few of the subjects, however, the seizure's onset occurred considerably later than usual; three others escaped the convulsions entirely. Seeking an answer for the resistance, Sterman examined his experimental protocol. He observed that the resilient cats had one thing in common: they had previously been involved in his conditioning tests. Could their ability to control their SMR waves have been a factor?

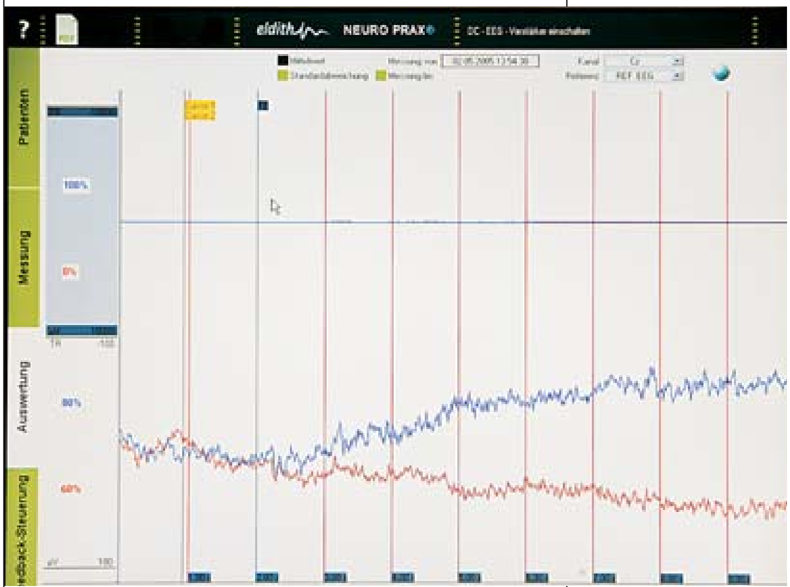
Sterman pursued the question in further experiments. In the early 1970s he found indications that people with epilepsy also could reduce their risk of seizures if they learned to heighten their SMR levels. Yet the idea remained controversial for lack of thorough study.

Brain Control

More than 30 years after Sterman's initial work with SMRs, scientists are exploring how neurofeedback might be used to treat a variety of ailments. In addition to SMRs, other brain waves at different frequencies characterize certain mental states [*see illustration on page 81*]. In deep sleep, for example, delta waves, with frequencies of up to 4 Hz and high amplitudes, dominate. Frequencies around 10 Hz, known as alpha waves, are present in a relaxed but awake brain; they emerge, for example, when we lie back with our eyes closed. If we then begin to concentrate on something, beta waves, with frequencies greater than 13 Hz, travel across the cortex. Lower-frequency theta waves appear when the brain relaxes. Theta waves, with high amplitudes and frequencies falling between those of delta and alpha waves, normally appear in adults during light sleep and meditation.

Regardless of frequency, there is no magic formula for learning how to harness one's brain waves. "Each subject must discover his own individual strategy, by trial and error," Leins explains. To increase brain activity, which steers the video plane upward, many children in the Tuebingen experiment say they think about something exciting—like jumping off a diving board. Ben imagines that he is spending a night camping in the woods. If the directional arrow points down, the boy tries to calm his brain to make the plane dip; in his thoughts, he lies down in bed and naps.

At Tuebingen, researchers working on epi-



To steer upward, Ben pushes the electrical potential of certain brain waves in an electrically negative (*blue*) direction. Flying down requires a positive direction (*red*).

(The Author)

ULRICH KRAFT, a physician and regular contributor to *Gehirn & Geist*, is a freelance science writer in Berlin.

lepsy therapy are looking at yet another component of the EEG, called slow cortical potential, or SCP. These brain waves can indicate activity in the cortex. Detecting them is useful, because epileptic seizures begin with overexcitement in cortical neurons, usually in a very limited area, from which brain activity spreads uncontrollably. The SCPs of patients shift in an electrically negative direction just before a seizure. Such negative slow potentials also arise normally in the brain. Therefore, the goal of neurofeedback is for patients to come to recognize this onset of electrical negativity and then to push their SCPs in the positive direction. Patients learn to limit brain activity consciously, thus suppressing an epileptic attack.

> After the sessions, the subjects performed better on evaluations of their attention and intelligence.

The method seems promising. In a 2001 study Niels Birbaumer and his colleagues at Tuebingen worked with epileptics who had not been helped by conventional medical therapies. On average, patients using SCP neurofeedback were able to reduce the number of seizures they suffered by a third. The positive effects lasted long after the training sessions had ended.

Mental Aerobics

Beta waves are the target of therapies for children with attention-deficit hyperactivity disorder, or ADHD. "It is exactly these higher-frequency brain waves that are, in children with ADHD, weaker compared with those in healthy children," Leins states. In the U.S., more than 700 groups are using EEG biofeedback to treat ADHD, according to the Association of Applied Psychophysiology and Biofeedback.

Children with ADHD struggle with schoolwork and social skills because they are restless, impulsive and have difficulty concentrating. Reduced levels of the higher-frequency brain waves are especially noticeable in the prefrontal cortex, an area involved in attention control. The kids also have an increase in lower-frequency waves, especially theta waves from 4 to 7.5 Hz. With neurofeedback, Leins says, "our ADHD subjects train their brains to produce fewer theta waves and thereby more beta waves."

Today Ben makes 45 "hits"—times when he has successfully lifted or lowered his brain activity at will. He gets five points on a gift card, and then he is free to leave. His mental exercises are not over for the day, however. Ben has been told to practice brain control in his everyday life, too. Before beginning homework, for example, he is to first imagine sinking a couple of baskets. Revving up the brain in this manner seems to help kids like Ben focus. "Many children say they can concentrate better after it and complete their homework more quickly," Leins says.

Ben and other children in the Tuebingen experiment train for 30 hours over several months. The researchers measure their cognitive performance immediately before and after treatment, using standardized tests especially geared to monitor attention. Six months after the therapy, they are checked again. After the neurofeedback sessions, the subjects performed better on evaluations of their attention and intelligence. Teachers reported that they were quieter and less impulsive in class. Many parents also said that their children had fewer problems doing homework. Leins sees these results as positive, though not definitive. "What we still lack are controlled studies of many children, which would compare this technique with other therapeutic methods," the researcher says.

Balancing Act

Many mental illnesses are accompanied by unusual brain-wave patterns, a fact that offers another possible therapeutic application for neurofeedback. Whether these variations are the cause or effect of such disorders is not always clear. At the least, the presence of such uncommon patterns may hinder recovery. In the early 1990s, for example, Richard J. Davidson, professor of psychology and psychiatry at the University of Wisconsin–Madison, noticed unusual asymmetries in the brain-wave patterns of people with depression. Apparently the distribution of alpha activity between the anterior parts of the right and left hemispheres can be associated with mood. Among depressive subjects, the pendulum swung to the right; their left hemispheres were comparatively less active.

With that in mind, psychologist J. Peter Rosenfeld of Northwestern University is trying to ease depression with neurofeedback. If patients could correct their own brain-wave patterns, Rosenfeld posits, they might be able to lift the gloom from their minds. So he and psychologists Elsa Baehr and Rufus Baehr of the NeuroQuest Neurofeedback Center in Evanston, Ill., developed a neurofeedback training program in the mid-1990s. Whenever the amplitude of alpha waves in the left frontal cortex rose above that in the right, the participants would hear a pleasant note played on a clarinet. During sessions lasting 15 to 30 minutes, the subjects worked to learn how to keep the tone in their ears for increasingly longer periods.

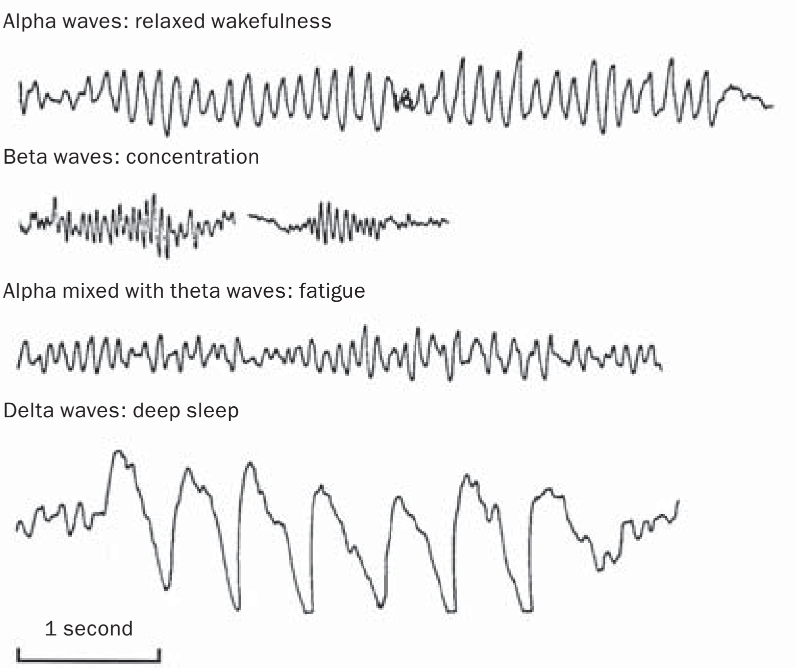
One spectacular case involved a woman who had previously been treated for recurrent bouts of depression for 12 years, without success. After just 35 hours of training, in combination with psychotherapy, her symptoms decreased drastically. In the subsequent six-year tracking period, she remained free of depression. Although the scientists can also point to successes with EEG feedback among other patients with depression, Elsa Baehr urges caution. "This is an experimental protocol," she notes. "Until there are controlled studies, we won't know how effective the therapy is."

Brain Boost?

In addition to therapies, could neurofeedback improve cognition in healthy brains? NASA, for one, has been using EEG biofeedback for years to increase concentration in its pilots.

To find out more, psychologist David Vernon, now at Canterbury Christ Church University in England, asked 40 volunteers to come to his lab. He and others wanted to find out whether deliberately influencing certain brain-wave patterns could boost working memory—which temporarily stores and manages information required to carry out complex cognitive tasks such as learning or reasoning. He first presented his subjects with a list of words. Then he gave them a category, such as "animals," and asked them to recall as many words from the list as possible that fit into that grouping.

Before training, the participants were able to remember just 71 percent of the words. In eight sessions, they learned to strengthen their SMRs—the same patterns that Sterman had worked with. After training, Vernon tested his subjects again, and this time they could remember almost 82 percent of the words. Vernon's group announced the results in January 2003. "Here we have the first evidence of a connection between neurofeedback and improvement in memory," Vernon claims.



Brain waves at certain frequencies characterize specific mental states.

A study published later that year supports the notion that brain-wave training can improve cognition. Neuroscientists Tobias Egner, now at Columbia University, and John H. Gruzelier, now at Goldsmiths, University of London, recruited test subjects at the Royal College of Music, London's elite school for promising young musicians. Some of the subjects learned, via feedback on a computer screen, how to control the slow waves in the alpha and theta ranges. After neurofeedback, the musicians' abilities had grown enormously, according to expert evaluators. The improvements came in such varied areas as musical understanding, stylistic precision and imaginative interpretation. What is more, the students made significantly fewer mistakes.

If further experiments confirm such results, neurofeedback may offer a suite of applications. Gruzelier, for example, is considering how SMR reinforcement could be used to train people whose professions require exceptionally steady hands, such as eye surgeons. **M**

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CIRCUIT TRAINING

Computer games for mental workouts

By Kaspar Mossman

"Your brain is in its 60s," Ryuta Kawashima announced. The disembodied head of the neuroscientist from Tohoku University in Japan wagged on the Nintendo screen and admonished: "If your brain is older than you, you should take note!"

Miffed, this 34-year-old biophysics Ph.D. candidate decided to do something about it. I would train my brain daily.

GETTY IMAGES

With many studies emphasizing the benefits of mental exercise for cognitive health, I knew I was not alone in my quest for a sharper mind. A 2002 federally funded study published in the *Journal of the American Medical Association,* for one, found that regular practice improved reasoning and memory in older adults. And, given the number of electronic puzzles and games arriving regularly on the market, companies are more than willing to help. To date, Nintendo has sold more than five million copies of brain games in Japan alone.

But what are they like to use? To find out, I decided to try out three new releases—all of which tout themselves as having been designed with the aid of scientists: Nintendo's Brain Age, Learning Enhancement Corporation's BrainWare Safari, and CyberLearning Technology's SmartBrainGames.

When FedEx delivered my advance copy, I eagerly jammed in the cartridge. Kawashima's visage appeared on the left screen, guiding me through a preliminary brain checkup: a "Stroop test." I was presented with the words "black," "blue," "red" and "yellow" in those colors—except that "black" was sometimes red and "yellow" was blue. (When you try to combine a routine, "automated" task, such as recognizing a color, with one that demands conscious attention, such as being able to name the word as "red" even if the type is "black," the result is "interference," or the Stroop effect. The phenomenon was first observed in the 1930s by John Ridley Stroop.) As instructed, I spoke the words aloud, careful not to let the colors distract me. The controller interpreted my voice.

> "Hmm," Kawashima mused. "Your brain seems to be a little tired, doesn't it?"

Let the Games Begin

Nintendo, king of thumb-reflex games such as Mario Bros., has long targeted teenagers who have the speed of a mongoose. But in April 2006, Nintendo unveiled Brain Age, a nifty game for adults that more reasonably requires only that we scribble with a plastic stylus. Brain Age ($19.99; Nintendo DS controller, $129.99) is the American cousin of Brain Training, which rocketed to popularity in Japan in 2005.

Brain Training was the brainchild of Kawashima, professor of neuroscience at Tohoku. His concept: your brain has an age of its own, independent of your body. If you do not use it, it gets old; if you do, it gets younger. The object of the game is to get your own brain age as low as possible. The ultimate goal is a brain age of 20. (Presumably people did not like being told they had the mind of a 13-year-old.) The controller calculates your score on various games and places you on a curve Kawashima obtained from testing real people ages 20 to 70.

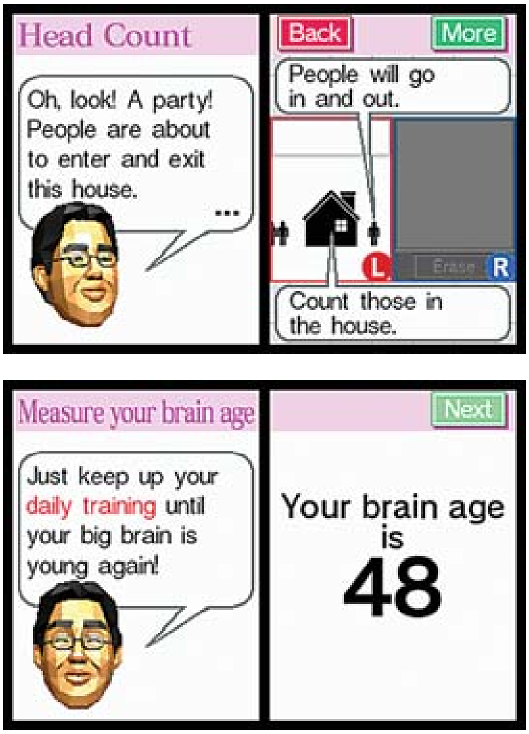
The controller folds out to resemble the dashboard of a small spaceship. To play Brain Age, however, you turn it sideways so it resembles a book. The touch-sensitive screen recognizes nearly illegible handwriting. As you write, speakers produce a pleasing raspy sound, as of a quill pen on parchment.

After I got the irritating news that my brain was at an age when many people are contemplating retirement, I progressed to daily training: quick arithmetic, reading aloud from classic books (Kawashima trusts you to be honest about when you turn the page), picking numbers out of a cloud of twirling, sliding decoys.

After what I thought was an awesome performance, Kawashima declared that my brain age was 51. "This is a wake-up call! I fear your brain is asking you for help!" Furious, I raced through the math exercises, glared at the lists of words for memorization, and counted numbers until my frontal lobes began to radiate heat through my forehead. "Hmm," Kawashima mused. "Your brain seems to be a little tired, doesn't it?"

It sure was the next morning. I had made the mistake of training my brain late at night and had set my cranium buzzing so fast it would not let me sleep. Over the next week, I practiced hard (in the mornings) and worked my brain age down. Of course, as with any video game, once I learned certain tricks, which had nothing to do with intelligence, my score improved. During an activity called Calculations × 100, for example, as the problems scrolled up the screen, I found I could look ahead and solve the next problem as my hand automatically wrote the previous answer.

On the third day Kawashima surprised me. "Draw a giraffe," he ordered. Then: "Africa."



Next, to humiliate me, he showed me a real giraffe and a real map of Africa. "Drawing objects from memory activates your prefrontal cortex!" As my scores improved, I was able to unlock new and more interesting games. Brain Age also allows multiple users; my fiancée insisted on playing, and we competed. She is a veterinarian and draws a mean giraffe. But her soft voice gave the controller trouble and slowed her on the Stroop test. "My brain age is 70!" she wailed. Unfortunately for my flagging sense of pride, that did not last long. She soon scored "younger" than I, and the brain age arms race was on.

After a week of exercises such as Low to High, Calculations × 100, and Head Count, were my synapses any slicker? It is hard to say, when there is no external yardstick against which to measure progress. But one week into brain training, while taking a phone message, I found I could effortlessly hold one 10-digit number in my head and scribble down another. Maybe Kawashima is onto something.

Heart of Smartness

When you hold information like a phone number in your head, you are using short-term memory, a key tool that the brain uses in processing speech. Short-term memory also comes into play in another learning game I tried, because it is a problem area for many people who struggle with mental disabilities. "I see children, adolescents and adults with various conditions all the way through cognitive dysfunction to brain injury," says Patricia Chunn, a clinical speech pathologist. "For many of these people, the biggest problem is memory." Chunn is scientific adviser to Learning Enhancement Corporation, a Chicago-based company. In July 2005 LEC released BrainWare Safari, software that is designed to improve cognition and memory in children ages six to 12. Safari, like Brain Age, knits logic puzzles and memory challenges into a gamelike setting. In Safari, however, the quest is for an *older* brain. You choose an animal—a monkey, jaguar, parrot or bear—who starts off as a toddler. The goal as you complete levels is to help your avatar friend grow up to be an adult, with business suit and briefcase.

To use Safari, you must connect to the Inter-

Neuroscientist Ryuta Kawashima exhorts players in Nintendo's Brain Age (*left*). Rather than using a joystick, users scrawl answers (*above*).

NINTENDO OF AMERICA, INC.

(The Author)

KASPAR MOSSMAN recently completed a Ph.D. in biophysics at the University of California, Berkeley. The last computer game he owned was Crystal Quest for the Macintosh Plus.

BrainWare Safari challenges kids to take a variety of tests with jungle themes.

LEARNING ENHANCEMENT CORPORATION

Positive reinforcement is relentless. “You have succeeded at this challenge!”

net. My trial user name and password were registered to my editor. I did not realize this mattered until I chose Moby Monkey and finished my first task, picking out a geometric shape that did not fit in a lineup. Moby skittered onto the screen in his diapers. “Good for you, Mariette!” Then he scampered back into the bush. My first thought: “I have to get that primate out of those ridiculous Pampers pronto.” My second: “If I fail any of these tests, at least it won’t be me who looks dumb.”

It is difficult to imagine what the average cyber-savvy eight-year-old would think of Safari’s somewhat clunky graphics. The home screen is a Peruvian panorama with volcanoes, Inca ruins, llamas and various jungly inhabitants depicted in bright colors. As you move your cursor around, cartoon blurbs pop up, challenging you to take tests such as Volcanic Patterns and Piranha Pass. In the center is the Safari Lodge, where I went to check how many tests remained before I could get Moby into some trousers. I quickly identified what did not belong inside the Andean hut: the Safari Guide, an explorer in khaki with a bristly mustache.

Shown a string of colored boxes and instructed to click five times to the beat before repeating the sequence, I belatedly realized there was a soundtrack. I found that recalling colors was much harder if I first had to match the rhythm. “Clicking forces [the processing task] into short-term memory,” Chunn says.

Safari ($349 for the first user, $200 for the second, $150 for others) was carefully planned and is under constant revision: psychologists, vision therapists and speech pathologists advise the designers. Positive reinforcement is relentless. “You have succeeded at this challenge!” “You should be very proud!” The comments from the animated characters quickly became too much, and I turned the sound off. But it is important to children, says Betsy Hill, LEC’s chief operating officer. “They get so excited when their character changes or the fireworks go off.” LEC plans to introduce a version for adults soon. BrainWare Vegas, anyone?

The author struggles heroically to get his brain in the zone (*above*). The task: race this hot rod (*right*) without losing your cool.

DOMENIC GRECO AND KASPAR MOSSMAN (*left*); © ELECTRONIC ARTS, INC. (*right*)

Get Your Motor Runnin'

Research also provides the foundation for SmartBrainGames, made by CyberLearning Technology in San Marcos, Calif. Compared with Brain Age and BrainWare Safari, SmartBrainGames feels like pure play—although it, too, is play with a purpose. It is intended for children with attentional difficulties or patients recovering from brain injuries such as concussions. The user plays a racing game on a Sony PlayStation while wearing electrodes to monitor brain waves. The object is to keep your brain waves calm while you zoom down the freeway, dodging slowpokes.

For SmartBrainGames ($595), CyberLearning licenses a NASA patent on using electroencephalographic feedback to modify a video game during play. I met Domenic and Lindsay Greco, co-founders of CyberLearning, at the Serious Games Summit in San Jose, Calif. Domenic explained about alpha, beta and theta waves—different low-frequency voltage oscillations that the brain produces—while Lindsay soaked three electrodes in electrolyte solution. The ratio of beta to alpha and theta waves produces what NASA calls the Engagement Index, a measure of attention to the task. The target mode corresponds to a range of this index. If you get too excited and your brain waves stray outside, you start to lose steering control and power.

Lindsay attached the electrodes, fitted into a visor: one behind my ear, one on the top of my head and one on my left temple. "With traditional neurofeedback devices," Domenic said, "you have to sit with the patients and motivate them." You do not need much encouragement with SmartBrainGames. I fired up my engine and accelerated onto the freeway. Suddenly, the handheld controller vibrated, another form of feedback. "See, you just lost steering," Domenic said. The car drove sluggishly. I strained to relax my brain waves, but no dice. The car slipped in and out of control. Bam! I rear-ended a van at 125 mph, and the car, windshield shattered, spun 360 degrees. I just did not have a feeling for what was needed.

"What you're trying to do is create conscious correlations—'What am I doing that's having that dramatic effect?'" Domenic added. "You'll get that as you work with the system on a more regular basis." In other words, I was trying too hard to feel an active connection between my brain and the game. According to Domenic, if I played SmartBrainGames for two weeks, my brain would find its way by trial and error into a state akin to that experienced by quarterback Joe Montana at the height of his powers.

I left the Serious Games Summit without having felt the mind-machine connection. Nevertheless, driving home in heavy traffic, I saw that crash over and over again in my mind, from all angles. I concentrated as hard as I could to keep my brain waves in the zone. **M**

(Further Reading)

- **Effects of Cognitive Training Interventions with Older Adults: A Randomized Controlled Trial.** Karlene Ball et al. in *Journal of the American Medical Association,* Vol. 288, No. 18, pages 2271–2281; November 13, 2002.
- **The Better Brain Book.** David Perlmutter and Carol Colman. Riverhead, 2004.
- **Train Your Brain: 60 Days to a Better Brain.** Ryuta Kawashima. Kumon Publishing, 2005.
- **www.happyneuron.com,** a Web resource for mental fitness.