

SCIENTIFIC AMERICAN **MIND**

THOUGHT • IDEAS • BRAIN SCIENCE

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Keep Killers
Out of Prison?

How Brilliance Arises **CREATIVITY** in Every One of Us

Déjà Vu Explained

**Mental Workouts
for Success**

Alien Impostors

**Does Brain
Equal Mind?**

**Sizing Up
Strangers**



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**Brain
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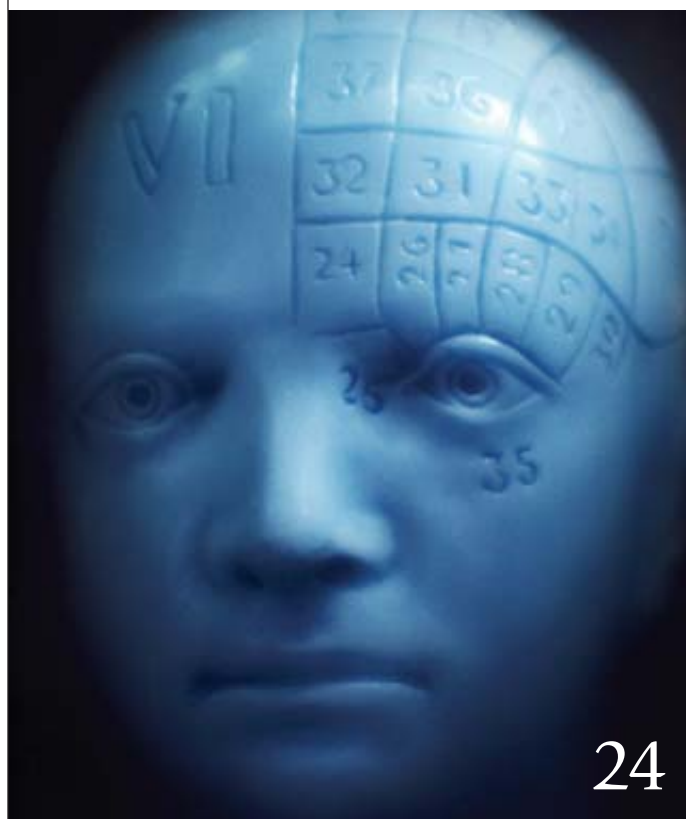
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Tapping the Muse

For me, the secret is always the lead—that’s journalist jargon for the opening of a story, the one provocative idea that will capture a reader’s interest. Once I’ve found that gem, the rest of the narrative seems to flow easily from the gray matter in my head down to my fingers pounding on the keyboard.

Where do such creative sparks come from? How can we conjure them whenever we want? And why can that be so infernally difficult to do, anyway? A complete understanding isn’t here yet, but neuroscientists are already on the trail of where and how creativity arises. They also have some good news for each of us who has ever struggled to ignite those inventive fires. As it turns out, tapping our own muse may be easier than we think, especially if we learn to make a habit of it. For more, turn to “Unleashing Creativity,” by Ulrich Kraft, on page 16.

Renaissance artist-engineer Leonardo da Vinci, renowned for such paintings as the *Mona Lisa*, seemed to suffer no lack of novel thoughts. In addition to artistic masterpieces, he designed flying machines, canals, a variety of buildings, and tanks. His successes make it clear, however, that imaginative genius isn’t enough to advance a brainchild. In “Leonardo da Vinci, Neuroscientist,” by Jonathan Pevsner, starting on page 84, you’ll see that another critical ingredient is the application of logic and systematic study to a fanciful notion. Leonardo—who lived in an era more comfortable with acceptance of prevailing wisdom than with experimentation—had the then unusual idea of examining and recording human anatomy for himself. As a result, he leaped beyond his contemporaries in developing a truer understanding of the brain.

We hope you find these and other articles in this issue of *Scientific American Mind* thought-provoking. And if the articles inspire you to write, please do.

Mariette DiChristina
 Executive Editor
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HUMANS CAN BE so pompous. Letter writers frequently expressed that sentiment regarding “The Samaritan Paradox,” by Ernst Fehr and Suzann-Viola Renninger, in the premier issue. The article mentioned how humans are more altruistic than would be strictly explainable in a world presumably governed by Darwinian “survival of the fittest.” It further posited that *Homo sapiens* may be unique in routinely demonstrating “strong altruism”—actions made to benefit others despite personal cost. Many readers indignantly pointed out that animals may feed or protect other, unrelated creatures in a similar fashion. Doing our part, we selflessly share these, and other topics, on the pages below.



MILK OF ANIMAL KINDNESS?

The article “The Samaritan Paradox,” by Ernst Fehr and Suzann-Viola Renninger, describes how altruism emerges spontaneously even in anonymous exchanges among people, whereas animal altruism starts and ends with kin.

I know of a documented case in which a crow fed a starving kitten worms and whatever else it could find. The crow literally put its beak into the kitten’s mouth to feed it. This would appear to be altruism that transcends kin. How do you explain such an act?

Ronke Olabisi
via e-mail

“**The Samaritan Paradox**” states that “a body of evidence supports the notion that *Homo sapiens* is the only species capable of strong altruism.” This is simply not true. In a recent example, in waters off New Zealand, dolphins guarded lifeguards-in-training from a shark. The dolphins swam in tight circles around the people and effectively herded them into a defensible position for 40 minutes until the swimmers were able to reach shore.

Surely there was no benefit to the dolphins—indeed, they wasted an extensive amount of energy in protecting the swimmers. Is this not strong altruism? Dolphins are not the only nonhuman animals to display such behavior. Similar instances have been found

among gorillas, chimpanzees, certain monkeys and rats.

Peter Mackey
Iqaluit, Nunavut, Canada

The Editors reply: *The authors did not say that animals do not show altruism. Their main argument is that large-scale cooperation in big groups of strangers does not occur among animals unless they are closely related genetically. This does not preclude single acts of altruism across species. It is natural to assume that humanlike rational intent must be governing certain seemingly selfless actions by animals. But these activities may also frequently be easily explained by instinct. A bird, for instance, is hardwired by evolution to fill an open mouth with food.*

In a particularly poignant example of the double-edged nature of such behavior, we know of a case in which a lioness in Kenya protected a series of baby oryx (a type of antelope). When one of the luckless ungulates starved to death under her care, she ate it. Where animal instinct ends and reasoning or feelings begin is an active line of scientific inquiry.

Fehr and Renninger missed one angle of exploration—self-identified ego boundaries. Philosopher Ken Wilber’s *A Brief History of Everything* examines levels of internal and external observation and understandings. I believe a significant factor in altruism is the

individual’s sense of identity. For some people, the sense of identity ends with their skin, possessions or status. Others extend it to include blood and marriage connections; friends, fraternal organizations or teams; community, their nation or their race. A few extend their sense of identity to the sum of humanity and even to all living things.

The people on the train volunteered to help the walletless passenger mentioned in the From the Editor column because they identified her as being in a zone of their sense of identity that was important enough for them to offer assistance. I believe all healthy people desire wellness for their zones of identity, and so they will act to serve that need after doing a quick calculation of the potential cost balanced against the importance of that zone to them.

Jim Kenney
Wainwright, Alberta, Canada

PROTECTING THE PATIENTS

Bravo to *Scientific American Mind* for its two articles on depression. “Antidepressants: Good Drugs or Good Marketing?” by David Dobbs, and “Treating Depression: Pills or Talk?” by Steven D. Hollon, Michael E. Thase and John C. Markowitz, tap into areas increasingly submerged within the domain of psychiatry.

As an R.N. and M.S.N., I wonder: What are we doing with our patients?

Does what we do make any difference? How are we empowering patients when we prescribe medication in instances where psychological interventions may provide better inoculation against recurrent illness, as well as enhancement of patients' adaptive capabilities? (In this vein, what are the social and economic costs?) And what are the long-term consequences for the discipline of psychiatry in terms of credibility of psychiatric treatment when the vaunted "evidence-based medicine" serves much less the master of science and more the machinations of Madison Avenue and Big Pharma? Bravo again!

Jeffrey J. Drury
Johnston, R.I.

OCCULT VERSUS FAITH

I found it quite troubling that "Casting Out the Demons," by Gunther Klosinski, mentioned the Christian God in a negative, unrealistic light. According to this article, "many psychologically healthy adults are enthralled

realm of the occult. I support the inclusion of future spiritual discussions in *Scientific American Mind*, but such articles should be written by individuals who demonstrate tolerance toward all faith systems.

Erik Gfesser
via e-mail

PREDISPOSITIONS AND CHOICE

I enjoyed "The Tyranny of Choice," by Barry Schwartz, but I have a critical comment: I don't think it's surprising that "maximizing persons" are "prime candidates for depression"—because they might already have been depressed. The maximizing behavior as a dysfunctional form of self-regulation reminds me of German psychologist Julius Kuhl's concept of "action orientation" versus "state orientation."

Kuhl defines the latter as the inability to escape a mode of control in which the initiation of intended behavior is difficult, as a result either of preoccupation (for example, rumination) or hesitation. The important thing here is to escape the state-oriented mode when needed, which will lead to balanced "opportunity costs." I think this is not so much a matter of choices but of predisposition. It is possible that the growing number of choices in our society fosters maximizers but that self-restricting habits might also arise from social circumstances. Growing up poor or with strict parents, for example, might be a predictor for becoming a "maximizer," I guess.

Türkan Ayan
Düsseldorf, Germany

mount psychological topic. Yet the suggestion that Illing might have mistaken James for B. F. Skinner distorts the position of Skinner.

As a cognitive psychologist, I am not a proponent of Skinner, but I do feel that it is incumbent on readers of a publication with the word "mind" in the title to understand his position. What made Skinner a "radical" behaviorist was not that he was more extremely against the mind than other behaviorists. Skinner contrasted methodological behaviorism with radical behaviorism. According to Skinner, "the part of methodological behaviorism I rejected was the argument that science must confine itself to events accessible to at least two observers ... and the behaviorism was therefore destined to ignore private events."

Skinner departed from methodological behaviorists by not eschewing the private. He made concepts such as consciousness public by stressing the reinforcing relationships among one's own behavior, the behavior of others (that is, culture), and the stimuli in the world. Thus, it is important to emphasize that Skinner did not deny the existence of consciousness.

Christopher H. Ramey
Department of Psychology
Florida Southern College

ERRATA "The Samaritan Paradox," by Ernst Fehr and Suzann-Viola Renninger, should have said that the human species "may be" rather than "is apparently" the only one with a genetic make-up that promotes strong altruism.

Credit for the images of glia cells on page 42 of "The Forgotten Brain Emerges," by Claudia Krebs, Kerstin Hüttmann and Christian Steinhäuser, was incorrectly attributed to "R. Douglas Fields, University of Maryland." The credit should have read: "Courtesy of R. Douglas Fields; Source: Derived from supporting online material for R. D. Fields and B. Stevens-Graham in *Science*, Vol. 298, pages 556–562; October 18, 2002. Used with permission." We regret this unfortunate mistake.



Conjuring spells, as Harry Potter demonstrates, is part of the occult's realm.

with everything from magic to the Holy Spirit, with no harm to themselves or others. The real question is: At what point does a person's involvement become dangerous?"

By any realistic definition of a faith system, Christianity is not within the

"RADICAL" SKINNER

In the Letters section, reader Fairfield M. Caudle rightly corrects Robert-Benjamin Illing, author of that issue's "Humbled by History," by stating that William James was nothing if not a champion of consciousness as a para-

Alzheimer's Vaccine?

Several years ago scientists at Elan, an Ireland-based drug company, and at U.S.-based Wyeth Pharmaceuticals developed a vaccine that showed prom-



ise in slowing the advance of Alzheimer's disease. The approach was to expose patients to a tiny amount of beta amyloid—the rogue protein thought to trigger the sticky plaques that accumulate in the brain. The exposure would prompt the body's immune system to raise its own disease-fighting antibodies to destroy the protein. But in January 2002, months into the clinical trials, it became apparent that serious brain swelling had developed in about 6 percent of patients. The trial was halted, hopes were dashed, and the researchers went back to square one.

Now investigators are recruiting people for a new trial. This time they will deliver the antibody itself to patients who have mild to moderate stages of the disease. Giving the antibody directly should not activate an immune response, says Dale Schenk, Elan's chief scientific officer. A faulty immune response is what causes dangerous

swelling. And “it doesn't take much antibody” to see if the new approach is working, Schenk says.

Other scientists have confirmed that the antibodies protect against plaque buildup. Schenk says subjects in the earlier trial who showed an elevated antibody response performed significantly better on memory tests. Evidence from autopsied brains of some of those who died also indicated reduced plaque formation.

The new study will test different doses for safety. And scientists should be able to tell if the antibodies alleviate some of Alzheimer's devastating mind-robbing symptoms. Eli Lilly and others are also working on antibody treatments, but none have reached patients yet. Of the few medicines federally approved to treat Alzheimer's, most improve symptoms temporarily by boosting a brain chemical that is key to memory and learning. —Jamie Talan

Head Lines

Distance Therapy

Forget the therapist's couch. Some psychiatrists may soon be talking to their clients over the phone. And scientists testing the treatment method say patients like it.

Gregory E. Simon and his colleagues at the Group Health Cooperative in Seattle followed 600 patients who were just beginning treatment with antidepressants. Over six months, counselors provided a third of the participants with eight phone therapy sessions lasting 30 to 40 minutes each. Another third received three brief calls intended to monitor their medication use. The final third received no intervention. At six months, all three groups were assessed.

Simon, a psychiatrist, reported that patients who participated in telephone therapy had lower scores than the others on a checklist for depression, meaning that they were less depressed. What is more, 80 percent rated themselves as “much improved” versus 66 percent for those who got the

three brief follow-up calls and 55 percent for those who just took their pills. Almost 60 percent who had long sessions said they were “very satisfied” with the approach.

In another study conducted by the Veterans Administration Medical Center in Maryland,

people received talk therapy administered over a video-phone link. Their level of satisfaction, indicated later, was as high as that expressed by patients who had face-to-face encounters with counselors.

These forms of teletherapy might be just what some doctors order, especially for individuals who are on the fence about starting counseling. Among psychotherapy beginners, Simon says, 25 percent attend just one session, only 50 percent make it beyond three sessions, and one quarter never even show up for the initial appointment. Phone

sessions could also help people overcome worries about stigma, as well as transportation problems. Simon says more research will be needed before insurance companies would consider reimbursement for phone therapy. —Jamie Talan





Finding Autism Earlier

Most autistic children are not diagnosed as such until they are three years old, and by then valuable time has already been lost. But Patricia K. Kuhl, a neuroscientist at the University of Washington, and her colleagues have discovered that certain neural and behavioral differences can be spotted in autistic children as young as two. The researchers plan to test whether they can similarly distinguish babies at six months of age. The goal is to create a screening tool that could identify a risk of autism as early as possible, “when the brain is so plastic,” Kuhl says. “That’s the time to get in and try to intervene.”

Children’s brains are wired for language by roughly their third year. Their language aptitude depends significantly on their ability to detect phonetic cues during those years as well as to attend to adult voices, notably their mother’s. Kuhl’s group compared these two skills in autistic children and in typically developing children between the ages of two and four.

The autistic preschoolers’ brains showed no response to a consonant change in a string of identical sounds (the phonetic cue). And they overwhelmingly preferred a computerized, nonspeech warble to samples of “motherese”—the expressive and elongated speech that mothers often use with young children, which, other research has shown, enhances language learning.

Kuhl thinks that certain infants will also show a clear preference for either motherese or the computer warble. If further research indicates that choosing a warble is predictive of autism, “then you would start really following those kids,” Kuhl says.

—Aimee Cunningham

Language Pathway Revealed

The long-standing 19th-century anatomical model of the brain’s language network just got a 21st-century upgrade. Marco Catani, a psychiatrist at the King’s College Institute of Psychiatry in London, and his colleagues have discovered a pathway that links the two primary language regions in the brain’s left hemisphere with a third region long suspected to contribute to human linguistic prowess. Found with a modified magnetic resonance imaging technique known as diffusion tensor tractography, the pathway affirms that “the circuit for language is more complex than we thought,” Catani says.

In the classic scheme, a bundle of nerve fibers called the arcuate fasciculus (red, at right) directly ties together Wernicke’s area, the site of spoken language comprehension (roughly behind the ear), to Broca’s area, the location of language production (behind the eye). The newfound pathway consists of two shorter fiber bundles that initially follow the arcuate fasciculus but end in the Geschwind territory of the inferior parietal lobe (toward the back of the head), an area thought to play a role in making language meaningful.

Although the indirect pathway will need to be verified by dissection—Catani suspects its proximity to the direct pathway has obscured its existence in the past—the virtual evidence matches actual nerve bundles found in monkey brains. The inclusion of the inferior parietal lobe in the language circuit could provide clues to how children develop language—the region is one of the last to mature in toddlers, and its full development coincides with the acquisition of complex language skills.

The pathway could also elucidate how language evolved. Catani says the correlation between human and primate anatomies suggests that “language is not due to a new structure of the [human] brain but somehow has developed from preexisting connections.”

—Aimee Cunningham



The Broca (top left) and Wernicke (bottom left) language regions have a direct connection (red), but newfound fiber bundles (green and yellow) bring the Geschwind territory (top right) into play, too.



Lone Neuron Cut

For decades, neuroscientists have destroyed nerves to study how well they can regenerate. Recently a team led by Stanford University physicist Mehmet Fatih Yanik (shown) brought new exactitude to this art by using a femtosecond laser to cut the outstretched arms, or axons, of individual nerve cells in the tiny worm *Caenorhabditis elegans*. The laser fires 40-nanojoule bursts that last only 200 quadrillionths of a second. It cut 0.3-micron gaps in motor neuron axons (inset) with so little surrounding damage that the axons regenerated within a day. Yanik says he is the first to slice lone neurons with a laser.

—David Dobbs

Chronic Collectors

Got too many stamps? Baseball cards? Vintage cars? Blame your brain.



Useless clothing fills an entire room of one hoarder's home.

About 70 animal species, including rats and crows, hoard things—mostly food but occasionally useless objects such as beads. Primitive brain regions, including the hippocampus and amygdala, are involved, but in humans higher brain structures are at work as well. Steven W. Anderson, a neurologist at the University of Iowa, recently studied 86 people who had lesions in various well-defined areas; of the total, 13 were “abnormal collectors,” filling their homes with everything from junk mail to spoiled food or broken appliances. Although the subjects had average intelligence and reasoning ability, they would not stop hoarding nor allow anything to be discarded. This kind of defiant behavior can sometimes cause serious personal and even legal problems, such as eviction.

Using high-resolution magnetic resonance imaging, Anderson found that all 13 had suffered damage to the right mesial frontal region. When this particular area is injured, “the very primitive collecting urge loses its guidance,” Anderson says. He hopes to extend his work to defining the origins of normal collecting behavior. —Jonathan Beard

Primates Protest: Unfair!

People aren't the only animals who know when they've gotten a raw deal. So do monkeys and chimpanzees, according to some clever experiments concluded recently at the Yerkes National Primate Research Center in Atlanta. The findings provide insight into how social environment and relationships sway human decision making, reports Sarah F. Brosnan, who conducted the studies with Frans de Waal at the center.

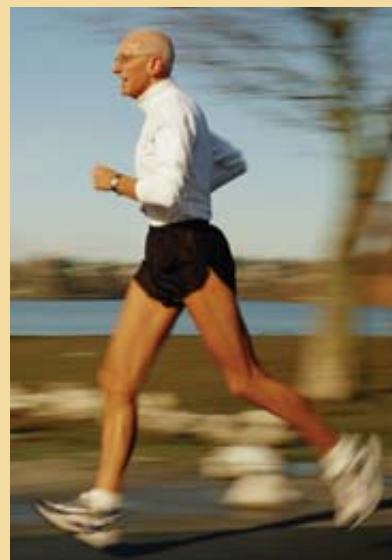
That nonhuman primates react to social unfairness suggests that such judgment is deeply rooted in evolution. In one experiment, Brosnan and de Waal gave female capuchin monkeys granite pebbles and asked them to hand the pebbles back to the researcher. Capuchins that did so received a sliver of cucumber. The monkeys completed the exchanges 95 percent of the time.

When scientists upped the reward to a coveted grape and gave it only to certain monkeys, the short-changed primates became less cooperative. Their apparent sense of inequity grew much more pronounced when the favored monkeys did not even have to perform a task for a grape; some of the offended animals refused to hand over the peb-



ble or threw their measly cucumber at the researcher.

Social relationships can temper dissatisfaction, however. In a separate study, chimpanzees that had been raised together and lived with one another for 30 years displayed no frustration when unequal rewards were given. But chimps that had met only as adults and lived together for eight years still became agitated at inequity. Brosnan says these reactions closely parallel human behavior. People are more likely, for example, to respond negatively to an unfair situation involving a stranger than they are with good friends or spouses. —Jamie Talan



Smart Exercise

Moderate physical activity in old age appears to invigorate the mind as well as the body. B. M. van Gelder of the National Institute for Public Health and the Environment in the Netherlands and his colleagues have found that elderly men who partake in moderately intense activities stay sharper than their less energetic counterparts.

In one of the few studies to assess physical activity and cognition over a long period, the researchers began in 1990 to track the exercise habits and mental abilities of 295 men ages 70 to 90. The subjects were monitored for an entire decade. Members of the lowest-intensity group, whose pursuits included playing billiards or walking at a pace less than three miles per hour, showed a cognitive decline that was up to 3.5 times greater than that of men who played volleyball or walked at three miles per hour (called the medium-low-intensity group). And yet men in the medium- and high-intensity categories (those who engaged in gymnastics or swimming, respectively) did about the same as the medium-low-intensity set, indicating that seniors can stave off some decline with just moderate exercise.

As for how exercise benefits mental capabilities, van Gelder's group speculates that it may be the result of better cardiovascular fitness, which boosts cerebral blood flow. Or the physical activity may stimulate brain cells in the hippocampus, the center of long-term memory.

—Aimee Cunningham

Big Pharma on Trial

It has been a depressing season for the drug industry, following reports of an alleged cover-up concerning suicidal risks in adolescents who take the widely prescribed selective serotonin reuptake inhibitors (SSRIs) to fight depression.

In October, a month after highly publicized advisory committee hearings about hiding data from drug trials [see “Antidepressants: Good Drugs or Good Marketing?” by David Dobbs; SCIENTIFIC AMERICAN MIND, Premier, 2004], the Food and Drug Administration required that SSRIs carry a “black box” label warning consumers of increased suicide risk among children and adolescents. At the same time, Merck was pulling from the market its lucrative arthritis medication, Vioxx, amid accusations it had failed to convey data about heart attack risks. And in December, GlaxoSmith-Kline, already accused of cherry-picking drug trial results about its antidepressant Paxil, faced reports from ABC News about additional documents supporting those charges.

Nearly lost amid this noise was fresh research about SSRIs. In October, *Science* reported that one SSRI given to young mice made them more anxious as adults, possibly by weakening the brain’s mood-modulating abilities. Then, in November, *Endocrinology* described how Prozac slowed

bone growth in young mice, lending experimental support to human studies suggesting that children who took SSRIs grew less than their peers.

For damage control, several drug companies and their trade group, the Pharmaceutical Research and Manufacturers of America, announced plans to publish all drug trial results—a measure critics dismissed because the practice would be voluntary. But David Graham, a chief drug safety officer at the FDA, had said at the Vioxx hearings that nothing less than an independent office would be needed to oversee the safety of drugs after their approval.

Many observers have since recommended that Congress require investigators to register every trial at its inception so doctors, journal editors and the public can assess all results for a given drug, not just positive ones that companies seek to publish. Industry watchdogs have been demanding such a registry for 25 years. Leading the charge, 11 high-profile medical journals stated that they would not publish the outcome of trials that had not been registered at the outset.

In an attempt to bring this activity to a head, Representatives Henry Waxman of California and Edward Markey of Massachusetts plan to reintroduce the Fair Access to Clinical Trials Act, which would create a federal registry. Its fate, observers say, will hinge on whether public and media pressure for change continues.

—David Dobbs



David Graham of the Food and Drug Administration testifies at U.S. Senate hearings that the American public is “virtually defenseless” if certain medications prove to be unsafe after they are approved for sale.

Zen Gamma

Researchers at the University of Wisconsin–Madison have found that during meditation, Zen Buddhist monks show an extraordinary synchronization of brain waves known as gamma synchrony—a pattern increasingly associated with robust brain function and the synthesis of activity that we call the mind.

Brain waves are produced by the extremely low voltages involved in transmitting messages among neurons. Most conscious activity produces beta waves at 13 to 30 hertz, or cycles per second. More intense gamma waves (30 to 60 or even 90 Hz) generally mark complex operations such as memory storage and sharp concentration.

The Wisconsin study took electroencephalograms (EEGs) of 10 long-time Buddhist practitioners and of a

control group of eight college students who had been lightly trained in meditation. While meditating, the monks produced gamma waves that were extremely high in amplitude and had long-

gamma waves were nowhere near as strong or tuned.

Such results connote more than spiritual harmony; they reflect the coordination of otherwise scattered

groups of neurons. Gamma synchrony increases as a person concentrates or prepares to move. And lack of synchrony indicates discordant mental activity such as schizophrenia. Finally, a growing body of theory proposes that gamma synchrony helps to bind the brain’s many sensory and cognitive operations into the miracle of consciousness.

That hypothesis certainly agrees with the monks’ gamma readings, seemingly confirming that Zen meditation produces not relaxation but an intense though serene attention.

Trained musicians also show superior gamma synchrony while listening to music—another form of calm but intense focus.

—David Dobbs



Monks tune their gamma waves at Eihei-ji Temple in Japan.

range gamma synchrony—the waves from disparate brain regions were in near lockstep, like numerous jump ropes turning precisely together. The synchrony was sustained for remarkably long periods, too. The students’

Gifted children who are not challenged can quickly grow bored with school, but a hidden fear of failure can lead to far greater problems
BY MARIE-NOËLLE GANRY-TARDY



Watching Prodigies for the Dark Side

JEFFREY IS JUST NOT interested in elementary school anymore. He doesn't retain what he is taught, and his grades are bad. At recess he avoids classmates and keeps to himself. He knows his parents are disappointed in him, too. His teacher finally recommends that he be taken to a child psychiatrist for evaluation. The therapist administers a special intelligence test, and Jeffrey turns out to have an IQ of 150—far above the average for his age. He is a highly gifted child.

Two to 3 percent of children are considered highly gifted, showing IQ scores of at least 130. For many such youngsters, their extraordinary intellect gives them a real advantage in school. They may shine in music, math or science. Contrary to popular belief, child prodigies do not on average have more school or social problems than

their less gifted peers, according to longitudinal studies. They may have fewer friends, but that is usually because they make greater demands of acquaintances.

And yet there is a dark side. For some of the most talented—those with IQs in the 140 to 150 range—their gifts can turn out to be a trap. Because these children are so insightful at such a young age, able to make sense of adult ideas, they are constantly aware of the potential risk of failure. This awareness can immobilize them to the point of emotional paralysis, a quiet demon that parents and teachers must watch for.

School tests pose one example. Unlike classmates who typically approach exams with a certain detachment and answer one question at a time, some highly gifted children relentlessly consider the implications of each answer

and what the risks are of making an error. Jeffrey's behavior reflected this constant sense of imminent failure. His fear caused his academic performance to be barely average. He also kept himself away from the other children because he doubted they would accept him.

Developmental disorders can exacerbate the trap. Dyslexia affects about 10 percent of children, regardless of their intelligence. The consequences are particularly severe for a highly gifted child. From the moment such a child enters school, he finds that he gets poor grades even though he comprehends everything easily. He therefore encounters difficulty understanding *why* his efforts meet with so little success. A steady diet of frustration eats at his self-esteem. The consequence is anxiety that may even shade into depression. As a defense, the child gradually loses interest in schoolwork and begins to isolate himself from social interaction. Punishment may only make matters worse. With their well-developed sense of right and wrong, prodigies

CORBIS

Some exceptional children are **constantly wary of failure**, leading them to emotional paralysis.

consider punishment undeserved, and they may withdraw further.

Moreover, with their heightened self-awareness, gifted children keenly feel a personal loss caused by any developmental disorders. For example, highly gifted children may be acutely aware of a lack of physical coordination or spatial orientation, which also undermines their self-image.

In some cases, IQ tests mislead parents and teachers as well. A gifted child might excel in questions that probe verbal intelligence, say, but perform miserably on spatial reasoning skills in the labyrinth part of the test. Because both scores are typically combined, the overall result may be just average. The discrepancy between the child's own high expectations and the discouraging evaluation from the adult world may lead a boy or girl up a blind alley that is hard to resolve. The ironic and unfortunate result is

that an extremely intelligent child may fail dramatically in school.

Catch It Early

So what is to be done? The first step is to recognize exceptional intelligence as well as developmental disorders so that parents and teachers can intervene. Earlier detection means quicker correction. For instance, in five-year-olds, phonics training can clear up dyslexia within six to 18 months. But if treatment begins only a year later, the correction can take twice as long—extending the chance that the child gives up on school.

Whether a child's spatial orientation is age-appropriate can be demonstrated by comparing performance on the verbal and nonverbal sections of an IQ test. If the nonverbal result is more than 10 points below the verbal result, psychomotor training is recommended. Drawings, games and sculpting can help a child

learn to coordinate his movements and improve spatial orientation. This kind of training is also most effective when begun by age five or six.

If the discrepancy between verbal and nonverbal IQ tests is greater than 20 percent, family therapy should also be considered, to improve interaction among family members. During the sessions, the therapist will try to assess how the child has developed and how the testing discrepancy might have arisen. Sometimes a child with motor or orientation problems will be afraid of simple daily tasks, such as tying her shoes. She knows she

will probably make mistakes and have to start over—perhaps enduring ridicule from siblings, parents or friends. If the parents try to help, they are unwittingly increasing her dependence on Mommy or Daddy. Yet if they are not around, she will quickly feel abandoned. To help the child regain her sense of independence, the therapist will try to get her to understand that failure is a normal part of life and not a catastrophe.

Child prodigies may also distort their own personalities to the point where they become unrecognizable. Psychiatrists call this the development of a false self. This problem may occur because these extraordinarily sensitive young people often feel deeply the subtle reactions of family members. As a result, they may overinterpret even the slightest sign of dissatisfaction. To please their parents, they deny their own needs and behave in a way they think matches their parents' expectations. They all but disappear behind a mask of compliance. To prevent this development of a false self, parents should offer a highly gifted child several varied activities and accept without judgment whatever the child chooses to pursue. It is important to encourage a child's special interests so that she does not lose motivation or a willingness to work.

Knowing the potential pitfalls within a child prodigy's world, and how to counter them, can significantly improve each girl and boy's chances for success with their double-edged gifts. And society will be more likely to benefit from their future contributions, whether in art, science, public service or wherever their brilliance leads them.

MARIE-NOËLLE GANRY-TARDY is a child psychiatrist in private practice in Paris who specializes in solving the problems of young gifted children.



Computer labyrinth tests can unveil spatial orientation problems in gifted children. Even in simple mazes, a child may not immediately recognize which path leads to the center, failing to see dead ends until he tries them (a, b). A child without a spatial deficit solves the puzzle directly (c).

Actions deemed odd, psychotic or even barbaric by one culture may be perfectly acceptable to another

BY STEVE J. AYAN AND IRIS TATJANA CALLIESS

Abnormal as Norm

CERTAIN MEN in Malaysia are driven by a fear that their genitals could retract up into their bodies. They even believe that the perceived condition, called *koro*, can be deadly. To prevent it, the men apply weights to their penises or take other extreme measures. The fear, and the uncomfortable antidote, is not common, yet it is accepted in this long-standing culture. But in a Western country, an adult male who acted on such a belief would certainly be labeled as emotionally disturbed.

This contradictory assessment and many others that arise between distant cultures put in sharp relief a strongly influential yet rarely discussed fact of psychology: cultural norms and values determine which behaviors are socially acceptable. In setting these standards, each society determines which mindsets and actions may constitute a psychological disorder. And societies do not necessarily agree.

Cult of Thinness

Ethnologists have described a wide variety of culturally dependent syndromes, many of which can be categorized as anxiety or compulsive disorders. Whereas *koro* seems psychotic to Westerners, Malaysians would most likely find very strange the American “cult of thinness” that seems to underlie a personality disorder that prompts women to deprive themselves of food.

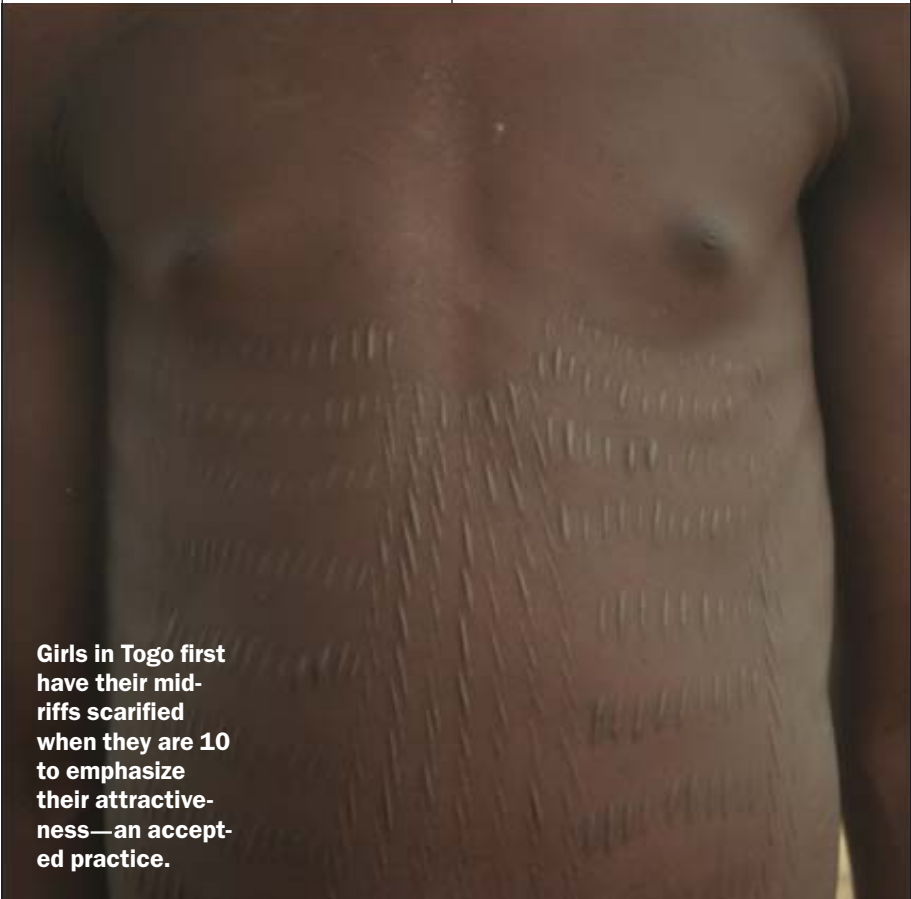
Some basic behavioral symptoms could be considered central to any kind of personality disorder, regardless of culture: Does an individual exhibit self-destructive behavior? Are symptoms intense and long-lasting? The real signature of a personality disorder, however, is a steady, long-held belief that makes it difficult for an individual to maintain his or her emotions, thoughts or actions at a socially acceptable level.

But what constitutes “socially acceptable”? In some Central and South American native tribes, adolescents cut their arms and wrists with sharp blades—an ancient initiation rite that leaves scars that mark them as members of the adult community. Though perfectly normal along the Amazon River, “cutting” in the U.S. has been established as a “personality disorder”—a pattern of emotional instability in relationships, self-image and mood that is marked by impulsiveness. Less exotic, local peculiarities can complicate the assessment of personality disorders, too. Taken out of their cultural contexts, the narcissism of the “Latin lover,” the fanatical work hours of the Japanese businessman, and the

screaming hysteria of British pop music fans at a live concert could all be taken as signs of trouble.

Researchers around the world have at times attempted to classify disorders and criteria to determine their diagnosis. Two resulting compendiums are now widely consulted: the *International Classification of Diseases and Related Health Problems*, published by the World Health Organization, now in its 10th edition, and the American Psychiatric Association’s *Diagnostic and Statistical Manual of Mental Disorders*, its most recent revised fourth edition released in 2000. The *ICD-10* and *DSM-IV-TR* are far-reaching, yet even they do not satisfactorily take into account the diversity of the world’s societies.

A few specialists known as cultural relativists are trying to fill the void by expanding the relatively new field of



Girls in Togo first have their mid-ribs scarified when they are 10 to emphasize their attractiveness—an accepted practice.

LUCILLE REYBOZ Corbis

“transcultural psychiatry.” Their efforts to organize the multiculturalism of mental illness will have to overcome the prevailing universalist perspective of traditional psychology: a patient’s culture does not play a major role in the development of psychological disorders. In this view, fundamental illnesses are the same the world over and vary only in how frequently they occur in a given culture.

By publishing its huge reference volume, the World Health Organization seems to share this assumption. Experts such as Cornell University psychiatrist Armand W. Loranger, who have tested the *DSM-IV-TR* and *ICD-10* criteria by interviewing patients from varied international backgrounds, have also concluded that cultural traits hardly play a role.

Yet one line of questioning in Loranger’s work revealed that avoidant and borderline personality disorders were not found in patient groups from India and Kenya, respectively, even though these are two of the most common syndromes worldwide. The reason is not



Female dieting would be considered emotionally disturbed in certain African and Indonesian nations.

ity disorders to people from other cultures. Chinese doctors have indeed developed their own classification system, and it does not include avoidant or dependent personality disorders. Should conditions such as these, then, be considered normal just because they are prevalent in a society? That could

McGill University supports this notion; he found that impulsive and emotionally unstable people—who are more prone to borderline disorders—exhibit clinical symptoms less often in more close-knit cultures.

As globalization steadily spreads, adequate diagnosis of patients from foreign cultures will become a more pressing issue. Therefore, psychologists and psychiatrists will have to become more cosmopolitan in their education; they should possess at least a rudimentary understanding of a patient’s culture and language or call on interpreters in their consultations. For example, a Turkish woman new to the U.S. who is suffering from depression would be more likely to complain of pain in various parts of her body rather than expressing feelings of sadness. This tendency toward so-called somatization is common in the Turkish culture yet could lead to a false diagnosis in Boston or Rio de Janeiro.

An understanding of cultural differences is important not only in the diagnosis of mental disorders but also in their treatment. Western-oriented

Taken out of cultural context, the Latin lover, Japanese businessman and screaming music fan could all be seen as troubled.

clear, but it is possible those from these cultures were loath to admit to symptoms, choosing instead to answer the related questions in what they thought was a socially acceptable way. This tendency could explain why a study by psychiatrist Wilson M. Compton of the National Institute on Drug Abuse showed a lower occurrence of antisocial personality disorders among Taiwanese patients than among Western ones. Compton found that politeness and passivity are highly regarded in the Far East and that the Taiwanese would rather not mention contrary impulses.

False Diagnosis

The multitude of differences among cultures clearly shows that mental health professionals are ill advised to apply their classifications of personal-

very well be the case. Norms define which types of behavior are acceptable, so if a certain trait is common in a society, then perhaps there is nothing “wrong” with it, regardless of how it might be perceived elsewhere.

According to several studies comparing cultures, personality disorders occur more frequently in industrial countries than in less developed ones, where closer social connections tend to dominate. In large families or village communities, roles are clearly defined and evolve very slowly, if at all. Like a cocoon, the community ensures that no individual experiences isolation or feelings of uselessness. In contrast, life in the modern, developed West is hectic and uncertain. Perhaps personality disorders are one price we pay for individual freedom. A study by Joel Paris of

psychotherapy is based on the idea that patients can evolve and are free to determine their own behavior. People from traditional, often highly religious societies are not served as well by such approaches. Their mental well-being stems from fulfilling the expectations of family and community. The goals of therapy for such people must be adjusted to meet their cultural needs.

The question of whether a common multicultural denominator of personality disorders can be expressed remains unanswered. Until that day comes, diagnosis will for the most part remain open to cultural interpretation.

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According to noted neurologist Antonio R. Damasio, joy or sorrow can emerge only after the brain registers physical changes in the body



Antonio Damasio has one of the world's largest databases of brain injuries.

Feeling Our Emotions

FOR CENTURIES, the fleeting and highly subjective world of feelings was the purview of philosophers. But during the past 30 years, Antonio R. Damasio has strived to show that feelings are what arise as the brain interprets emotions, which are themselves purely physical signals of the body reacting to external stimuli.

Born in 1944 in Lisbon, Portugal, Damasio has been chair of the University of Iowa's neurology department since 1986. He and his wife, neurologist Hanna Damasio, have created one of the world's largest databases of brain injuries, comprising hundreds of studies of brain lesions and diagnostic images. As profound as some of the damage is to Antonio Damasio's patients, all of it informs his understanding of how emotions and feelings arise

and how they can affect mental illness.

In recent years, Damasio has become increasingly interested in the role emotions play in our decision-making processes and in our self-image. In several widely popular books, he has shown how certain feelings are cornerstones of our survival. And today he argues that our internal, emotional regulatory processes not only preserve our lives but actually shape our greatest cultural accomplishments.

—Interview by Manuela Lenzen

MIND: Professor Damasio, why are you so fascinated by the nature of human emotion?

Antonio R. Damasio: At first I was interested in all types of neurological injuries. If one area of the brain would lose its ability to function, the patient's

behavior could change either dramatically or only subtly. One day I asked myself, What is missing in a person who can pass an intelligence test with flying colors but can't even organize his own life? Such patients can hold their own in completely rational arguments but fail, for example, to avoid a situation involving unnecessary risk. These kinds of problems mainly occur after an injury to the forebrain. As our tests prove, the result is a lack of normal emotional reactions. I continue to be fascinated by the fact that feelings are not just the shady side of reason but that they help us to reach decisions as well.

MIND: You differentiate between feelings and emotions. How so?

Damasio: In everyday language we often use the terms interchangeably. This shows how closely connected emotions are with feelings. But for neuroscience, emotions are more or less the complex reactions the body has to certain stimuli. When we are afraid of something, our hearts begin to race, our mouths become dry, our skin turns pale and our muscles contract. This emotional reaction occurs automatically and unconsciously. Feelings occur after we become aware in our brain of such physical changes; only then do we experience the feeling of fear.

MIND: So, then, feelings are formed by emotions?

Damasio: Yes. The brain is constantly receiving signals from the body, registering what is going on inside of us. It then processes the signals in neural maps, which it then compiles in the so-called somatosensory centers. Feelings occur when the maps are read and it becomes apparent that emotional changes have been recorded—as snapshots of our physical state, so to speak.

MIND: According to your definition, all feelings have their origin in the physical. Is that really the case?

“Contrasting the negative emotions such as sadness with joy can lead to **inner peace** and stoic equanimity.”

Damasio: Interestingly enough, not all feelings result from the body’s reaction to external stimuli. Sometimes changes are purely simulated in the brain maps. For example, when we feel sympathy for a sick person, we re-create that person’s pain to a certain degree internally. Also, the mapping of our physical state is never completely exact. Extreme stress or extreme fear and even physical pain can be dismissed; the brain ignores the physical signals that are transmitting the pain stimulus.

MIND: The differentiation between emotions and feelings brings to mind 17th-century philosopher René Descartes’ idea of dualism—that the body and mind represent autonomous systems. But you reject that idea, as you explain in your book *Descartes’ Error*. How should we see the relationship between mind and body?

Damasio: To me, body and mind are different aspects of specific biological processes. Philosopher Baruch Spinoza supported views similar to mine, regarding the body and soul question, shortly after Descartes’ time. In his *Ethics* he wrote: “The object of the idea which constitutes the human mind is body.” Spinoza thereby anticipated the findings of modern neurobiology.

MIND: Indeed, in your latest book, *Looking for Spinoza*, you describe the man as “a mental immunologist developing a vaccine capable of creating antipassion antibodies.” So is only a life free of passions a good life?

Damasio: Spinoza fascinates me not only because he was ahead of his time with his ideas on biology but also for the conclusions he drew from these ideas about the correct way to live life and set up a society. Spinoza was a very life-affirming thinker. He recommended contrasting the negative emotions such as sadness and fear with joy, for example. He understood this

kind of practice as a way to reach an inner peace and stoic equanimity.

MIND: What are some of the other functions that feelings have, in addition to helping us make decisions?

Damasio: My interest now extends way past the question of decision making. In our lab, we are working more intensely with social feelings such as sympathy, shame or pride—they form



“Adults would be helpless if they lost their self-image.”

a foundation for morality. Neurobiology doesn’t simply help us to better understand human nature but also the rules of social interaction. Yet to really grasp this, we need a broader research approach: along with cognitive and neurological sciences, many of the humanities could contribute, especially anthropology and sociology.

MIND: It seems your research also extends into defining consciousness. What role do emotions play? What role does the body play?

Damasio: Consciousness, much like our feelings, is based on a representation of the body and how it changes when reacting to certain stimuli. Self-image would be unthinkable without this representation. I think humans

have developed a self-image mainly to establish a homeostatic organism. The brain constantly needs up-to-date information on the body’s state to regulate all the processes that keep it alive. This is the only way an organism can survive in an ever changing environment. Emotions alone—without conscious feelings—would not be enough. Adults would be as helpless as babies if they suddenly lost their self-image.

MIND: Animals also must possess consciousness, then?

Damasio: I do believe that animals develop a very basic self-concept—what I refer to as “core self.” But to have a broader self, such as we do, requires an autobiographical memory.

MIND: Do you believe that we will someday be able to create artificial consciousness and feelings?

Damasio: An organism can possess feelings only when it can create a representation of the body’s functions and the related changes that occur in the brain. In this way, the organism can perceive them. Without this mechanism there would be no consciousness. It is unclear that this could ever develop in a machine or whether we really want machines with feelings.

MIND: Will research on emotions help lead to better forms of therapy for psychiatric illnesses?

Damasio: Without question. Emotional disorders form the core of most psychological illnesses—a good example of this is depression. Specific treatments will be developed in the future, such as new types of medicine that target distinct cellular and molecular systems. Other forms of therapy are also sure to benefit, from traditional psychotherapy to social intervention.

MANUELA LENZEN is a philosopher and writer in Bielefeld, Germany.

UNLEASHING **Core**



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Moments of brilliance arise from complex cognitive processes. Piece by piece, researchers are uncovering the secrets of creative thinking

By Ulrich Kraft



JANCY CHANG

Jancy Chang, a high school art teacher in San Francisco, had been painting since she was a child. She varied her technique from Western-style watercolors to classical Chinese brushstrokes, but she always strove for realism: painting landscapes and people in social settings as literally as she could. Then, in 1986, at age 43, she began to have problems performing her job. Grading, preparing for class, putting together lesson plans—everything that she had previously done with ease—became increasingly difficult over the next few years. By 1995 she could no longer remember the names of her students and was forced to take early retirement.

Understandably frightened, Chang had started seeing neurologist Bruce L. Miller, clinical director of the Memory and Aging Center at the University of California at San Francisco. He diagnosed her with fronto-temporal dementia. This relatively rare form of dementia selectively damages the temporal and frontal lobes, primarily in the brain's left hemisphere. These regions control speech and social behavior and are intimately involved in memory. Patients often become introverted, exhibit compulsive behaviors and lose inhibitions that would otherwise prevent them



Art teacher Jancy Chang sought realism in her own work, like *Jahua House* (above), but as dementia set in, her paintings became increasingly imaginative, like the wildly impressionistic *Four Masks* (preceding pages).

from acting inappropriately toward others in social settings.

Miller observed all these changes in Chang, but he also found that her creative powers were growing remarkably. “The more she lost her social and language abilities, the wilder and freer her art became,” he notes. The same lack of inhibition that caused embarrassing moments in public allowed her to break the shackles of her realism art training and become increasingly impressionistic and abstract. Her paintings were much more emotionally charged.

Miller was astonished. The last place he expected talent to bloom was in the brain of a person whose mental functions were deteriorating because of crumbling neurons. But it turned out that Chang was not an isolated case. Miller later identified other men and women whose latent creativity burst forth as frontotemporal dementia set in—even in patients who had little prior interest in artistic pursuits. One man, a stockbroker who had never before been touched by the muse, traded his conservative suits for the most radical styles he could find. He developed a passion for painting and went on to win several art prizes. Another person began to compose music even though he had no musical training. A third invented a sophisticated chemical detector at a stage when he could recall only one in 15 words on a memory test.

The ability to create is one of the outstanding traits of human beings. From harnessing fire to splitting the atom, an inexhaustible stream of innovative flashes has largely driven our social development. Significant insight into the neuronal mechanisms underlying the creative thought pro-

cess is coming from work with patients who, like Chang, have suddenly acquired unusual skills as a result of brain damage. Using technical advances such as functional magnetic resonance imaging and electroencephalography, neuroscientists are trying to determine just where those sparks originate.

Scientific understanding of creativity is far from complete, but one lesson already seems plain: originality is not a gift doled out sparingly by the gods. We can call it up from within us through training and encouragement. Not every man, woman or child is a potential genius, but we can get the most out of our abilities by performing certain kinds of exercises and by optimizing our attitudes and environment—the same factors that help us maximize other cognitive powers. Some of the steps are deceptively simple, such as reminding ourselves to stay curious about the world around us and to have the courage to tear down mental preconceptions [see box on opposite page]. Steven M. Smith, a professor of psychology at the Institute for Applied Creativity at Texas A&M University, says many people believe that only a handful of geniuses are capable of making creative contributions to humanity: “It just isn’t true. Creative thinking is the norm in human beings and can be observed in almost all mental activities.”

The ease with which we routinely string together appropriate words during a conversation should leave no doubt that our brains are fundamentally creative. What scientists are trying to discover is why the engine of inspiration seems to be always in high gear in some people while others struggle.

JANCY CHANG

Afflicted people lose regard for social norms, yet this lack of inhibition allows artistry to bloom.

It's Not Intellect

Intelligence is not a crucial ingredient. U.S. military leaders recognized this seeming contradiction more than 50 years ago. During World War II, the U.S. Air Force sought to identify fighter pilots who would be able to get out of jams in unorthodox ways. Officials wanted pilots who would not simply bail out in an emergency but who would be more likely to save themselves and their aircraft. Initially, military scouts used conventional intelligence tests to identify such candidates. But they soon realized a high IQ was useless in finding inventive superpilots, and they resorted to more anecdotal measures.

Around the same time, psychologist Joy Paul Guilford of the University of Southern California noted that intelligence did not mirror the totality of a person's cognitive capacity. In the late 1940s Guilford developed a model of human intellect that formed the basis for modern research into creativity. A crucial variable is the difference between "convergent" and "divergent" thinking.

Convergent thinking aims for a single, correct solution to a problem. When presented with a situation, we use logic to find an orthodox solution and to determine if it is unambiguously right or wrong. IQ tests primarily involve convergent thinking. But creative people can free themselves from conventional thought patterns and follow new pathways to unusual or distantly associated answers. This ability is known as divergent thinking, which generates many possible solutions. In solving a problem, an individual proceeds from different starting points and changes direction as required, which Guilford explained leads to multiple solutions, all of which could be correct and appropriate.

Guilford tried to find a measurable "creativity quotient" analogous to IQ, but his efforts and those of other researchers since his time have all failed. A few techniques, such as the Torrance Test of Creative Thinking, can give a sense of which people in a test group may be more creative [see box on next page]. But deciding which of their many responses can be characterized as especially creative is simply too dependent on the personal judgment of the tester.

Rather than using a standardized test, today's creativity experts look for certain characteristics that people who excel at divergent thinking seem

to exhibit. The following are prime examples:

Ideational fluency. The number of ideas, sentences and associations a person can think of when presented with a word.

Variety and flexibility. The diversity of different solutions a person can find when asked to explore the possible uses of, say, a newspaper or a paper clip.

Originality. The ability to develop potential solutions other people do not reach.

Elaboration. The skill to formulate an idea, expand on it, then work it into a concrete solution.

Problem sensitivity. The ability to recognize the central challenge within a task, as well as the difficulties associated with it.

Redefinition. The capacity to view a known problem in a completely different light.

Steps to a Creative Mind-set

Wonderment. Try to retain a spirit of discovery, a childlike curiosity about the world. And question understandings that others consider obvious.

Motivation. As soon as a spark of interest arises in something, follow it.

Intellectual courage. Strive to think outside accepted principles and habitual perspectives such as "We've always done it that way."

Relaxation. Take the time to daydream and ponder, because that is often when the best ideas arise. Look for ways to relax and consciously put them into practice.

Left or Right?

Guilford's distinction between convergent and divergent thinking prompted neuroscientists to examine whether the two processes took place in different brain regions. Their experiments, particularly those conducted in the 1960s by psychobiologist Roger W. Sperry of the California Institute of Technology, revolutionized neurology and psychology. Sperry worked with so-called split-brain patients who suffered from epilepsy that did not respond to conventional medical

Schools place overwhelming emphasis on solving problems correctly, not creatively.

treatment. The only way to end their horrible seizures was to surgically sever their corpus callosum, the fibrous structure that links the brain's left and right hemispheres.

Sperry and his colleague Michael Gazzaniga, now at Dartmouth College, put patients through a series of sophisticated experiments, which led to the breakthrough discovery that the left and right hemispheres do not process the same information. Sperry won the 1981 Nobel Prize in Physiology or Medicine for the work. Among other duties, the left hemisphere is responsible for most aspects of communication. It processes hearing, written material and body language. The right hemisphere processes images, melodies, modulation, complex patterns such as faces, as well as the body's spatial orientation.

The functional differences between the hemispheres are the subject of intense research today. Studies of stroke patients confirm the basic division of labor. Damage to the right hemisphere, for example, leaves speech largely intact but harms body awareness and spatial orientation. But researchers have noted another interesting correlation: patients with right hemisphere strokes lose whatever creative talents they had for painting, poetry, music, even for playing games such as chess.

The accumulation of experimental evidence now proves that the left hemisphere is responsi-

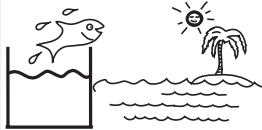
ble for convergent thinking and the right hemisphere for divergent thinking. The left side examines details and processes them logically and analytically but lacks a sense of overriding, abstract connections. The right side is more imaginative and intuitive and tends to work holistically, integrating pieces of an informational puzzle into a whole.

Consider a poem. When an individual reads it, his left hemisphere analyzes the sequence of letters and integrates them into words and sentences, following the logical laws governing written language. It checks for grammatical and morphological meaning and grasps the factual content. But the right hemisphere interprets a poem as more than a string of words. It integrates the information with its own prior ideas and imagination, allows images to well up, and recognizes overarching metaphorical meaning.

Creativity Unleashed

The right hemisphere's divergent thinking underlies our ability to be creative. Curiosity, love of experimentation, playfulness, risk taking, mental flexibility, metaphorical thinking, aesthetics—all these qualities play a central role. But why does creativity remain so elusive? Everyone has a right hemisphere, so we all should be fountains of unorthodox ideas.

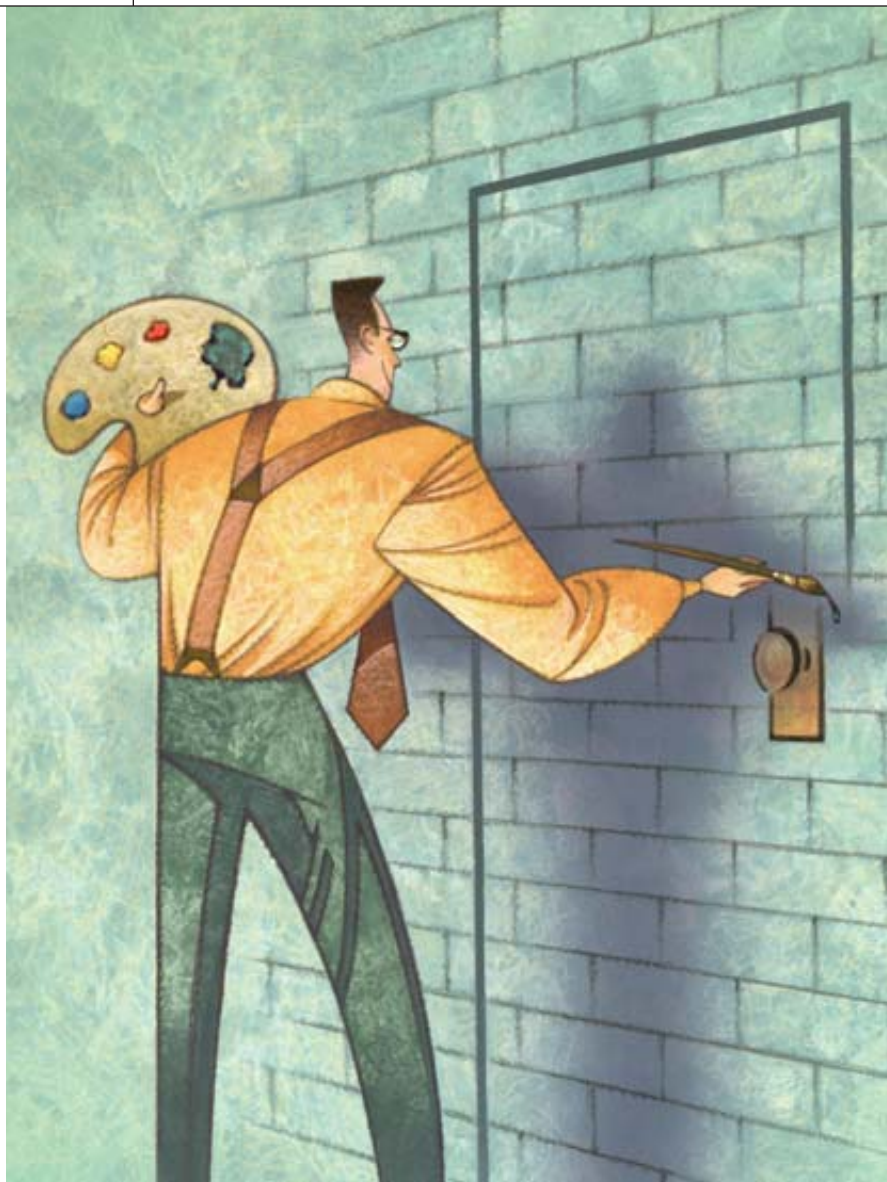
Consider that most children abound in inno-

Torrance Test	Starting Shapes	Completed Drawing	
		More Creative	Less Creative
In a standardized Torrance Test of Creative Thinking, subjects are given simple shapes (<i>left column</i>) and are asked to use them (<i>top row</i>) or combine them (<i>middle row</i>) in a picture or to complete a partial picture (<i>bottom row</i>). Evaluators judge whether the results are more or less creative.	Use 	 Mickey Mouse	 Chain
	Combine 	 King	 Face
	Complete 	 A fish on vacation	 Pot

vative energy: a table and an old blanket transform into a medieval fortress, while the vacuum cleaner becomes the knight's horse and a yardstick a sword. Research suggests that we start our young lives as creativity engines but that our talent is gradually repressed. Schools place overwhelming emphasis on teaching children to solve problems correctly, not creatively. This skewed system dominates our first 20 years of life: tests, grades, college admission, degrees and job placements demand and reward targeted logical thinking, factual competence, and language and math skills—all purviews of the left brain. The propensity for convergent thinking becomes increasingly internalized, at the cost of creative potential. To a degree, the brain is a creature of habit; using well-established neural pathways is more economical than elaborating new or unusual ones. Additionally, failure to train creative faculties allows those neural connections to wither. Over time it becomes harder for us to overcome thought barriers. Creativity trainers like to tell clients: "If you always think the way you always thought, you'll always get what you always got—the same old ideas."

Bruce Miller's examination of Jancy Chang and other patients like her lends credence to the notion that the logical left hemisphere may block the creative right side. With the help of imaging techniques, Miller has determined that people with frontotemporal dementia lose neurons primarily in the left hemisphere. Patients have trouble speaking and show no regard for social norms. And yet this very lack of inhibition allows dormant artistic talents to bloom. Miller draws parallels to creative geniuses such as Vincent van Gogh and Francisco Goya, who ignored social expectations and developed unorthodox styles that opposed contemporary conventions. Great artists often exhibit an ability to transcend social and cognitive walls.

Nevertheless, it is wrong to assume that the left hemisphere is all that stands in the way of genius. Not every unconventional idea is necessarily a good one; many completely miss a problem at hand or are simply outlandish. The most



important creative work is useful, relevant or effective. And it is the left hemisphere that conducts this self-evaluation as creative thoughts bubble up from the right. As Ned Herrmann, artist, actor, management trainer and author of *The Creative Brain* (Ned Herrmann Group, 1995), notes, the left brain keeps the right brain in check. Creativity involves the entire brain.

Voyage of Discovery

Convergent thinking is also required for a creative breakthrough. Inspirational thunderbolts do not appear out of the blue. They are grounded in solid knowledge. Creative people are generally

Creativity can be unlocked by viewing conventional wisdom with fresh eyes.

(The Author)

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(All of us can call up originality from within our minds through training and encouragement.)

very knowledgeable about a given discipline. Coming up with a grand idea without ever having been closely involved with an area of study is not impossible, but it is very improbable. Albert Einstein worked for years on rigorous physics problems, mathematics and even philosophy before he hit on the central equation of relativity theory: $E=mc^2$. As legendary innovator Thomas A. Edison, author of 1,093 patents, noted drily, “Genius is 1 percent inspiration and 99 percent perspiration.”

Various psychologists have floated different models of the creative process, but most involve an early “preparation” phase, which is what Edison was talking about. Preparation is difficult and time-consuming. Once a challenge is identified, a person who wants to solve it has to examine it from all sides, including new perspectives. The process should resemble something like an intellectual voyage of discovery that can go in any direction. Fresh solutions result from disassembling and reassembling the building blocks in an infinite number of ways. That means the problem solver must thoroughly understand the blocks.

Smith of Texas A&M emphasizes how important it is to be able to combine ideas. He says people who are especially inventive have a gift for connecting elements that at first glance may seem to have nothing in common. To do that,

one must have a good grasp of the concepts. The more one knows, the easier it will be to develop innovative solutions.

In this context, psychologist Shelley H. Carson of Harvard University reached an interesting insight in 2003. She analyzed studies of students and found that those who were “eminent creative achievers”—for example, one had published a novel, another a musical composition—demonstrated lower “latent inhibition” on standard psychological tests than average classmates. Latent inhibition is a sort of filter that allows the brain to screen out information that has been shown by experience to be less important from the welter of data that streams into our heads each second through our sensory system. The information is cast aside even before it reaches consciousness. Think about your act of reading this article right now; you have most likely become unaware that you are sitting in a chair or that there are objects across the room in your peripheral vision.

Screened data take up no brain capacity, lessening the burden on your neurons. But they are also unavailable to your thought process. Yet because creativity depends primarily on the ability to integrate pieces of disparate data in novel ways, a lower level of latent inhibition is helpful. It is good to filter out some information, but not too much. Then again, lower latent inhibition scores have been associated with psychosis.

Latent inhibition has a corollary: too much specialized knowledge can stand in the way of creative thinking. Experts in a field will often internalize “accepted” thought processes, so that they become automatic. Intellectual flexibility is lost. For example, a mathematician will very likely tackle a difficult problem in an analytical way common to her professional training. But if the problem resists solution by this method, she may



OSWALD HUBER

Inhibition Lost

When brain tissue in the frontotemporal lobes atrophies, typically because of dementia, victims often lose their inhibitions. This change can lead to increasingly inappropriate social behavior, such as loud outbursts or making sexual references. Ironically, the lack of self-control can also markedly enhance creative thinking and talents such as painting and sculpture. Vincent van Gogh fit this profile perfectly late in his career; at the right is a work of his from 1888, two years before his death.



well find herself at a mental dead end. She has to let go of the unsuitable approach.

The Bathtub Principle

Letting go to gain inspiration may be difficult. One aid is to simply get away from the problem for a while. Creativity does not prosper under pressure. That is why so many strokes of genius have occurred outside the laboratory, in situations that have nothing to do with work. Legend has it that when Greek mathematician and mechanical wizard Archimedes was stepping into a bathtub when the principle of fluid displacement came to him—the original “eureka!” moment. Organic chemist Friedrich August Kekulé had a dream about snakes biting their own tails; his eureka moment occurred the next morning, when he depicted the chemical structure of benzene as ring-shaped.

Creative revelations come to most people when their minds are involved in an unrelated activity. That is because the brain continues to work on a problem once it has been supplied with the necessary raw materials. Some psychologists call this mental fermentation or incubation. They surmise that associative connections between ideas and imagination that already exist in the mind become weaker and are transformed by new information. A little relaxation and distance changes the mind’s per-

spective on the problem—without us being aware of it. This change of perspective allows for alternative insights and creates the preconditions for a fresh, and perhaps more creative, approach. The respite seems to allow the brain to clear away thought barriers by itself. At some point, newly combined associations break into consciousness, and we experience sudden, intuitive enlightenment.

The little insights and breakthroughs we all experience should encourage us to believe that bigger eureka moments are possible for anyone. Our brains bestow moments of illumination almost as a matter of course, as long as there has been adequate preparation and incubation. The catch is that because the neural processes that take place during creativity remain hidden from consciousness, we cannot actively influence or accelerate them. It therefore behooves even the most creative among us to practice one discipline above all—patience.

(Further Reading)

- ▣ **Artistic Creativity and the Brain.** Semir Zeki in *Science*, Vol. 293, pages 51–52; July 6, 2001.
- ▣ **Creativity and the Mind: Discovering the Genius Within.** T. B. Ward, R. A. Finke and S. M. Smith. Perseus Publishing, 2002.
- ▣ **Decreased Latent Inhibition Is Associated with Increased Creative Achievement in High-Functioning Individuals.** S. H. Carson, J. B. Peterson and D. M. Higgins in *Journal of Personality and Social Psychology*, Vol. 85, No. 3, pages 499–506; September 2003.



MRI machine is juxtaposed with a model of the human head with phrenology markings (*opposite page*), an outmoded attempt to assign personality traits based on the skull's shape.



The growing
controversy over
fMRI scans
is forcing us to
confront whether
brain equals mind
By David Dobbs

Phrenology?

unctional magnetic resonance imaging—or fMRI—has made quite a splash since its introduction a decade ago. Operating at spatial dimensions and time-scales far finer than previous brain-scanning techniques, it has sparked great excitement by letting us finally watch the brain at work. Thousands of fMRI studies have explored a wide range of differences in brain activation: adolescents versus adults, schizophrenic and normal minds, the empathetic and the impassive. Researchers have used fMRI to draw bold conclusions about face and word recognition, working memory and false memories, people anticipating pain, mothers recognizing their children, citizens pondering ethical dilemmas—not to mention why many consumers buy Coke even though they really prefer the taste of Pepsi. Psychologists have praised fMRI for finally making their science more quantifiable. And cognitive neuroscientists have cited the scans heavily in the recent, vast expansion in understanding of the brain.

Increasingly, however, arguments are stirring over the reliability of fMRI findings. This debate, at once technical and philosophical, concerns both fMRI's accuracy, because it measures neuronal activity indirectly by detecting associated increases in blood flow, and its legitimacy in linking complex men-

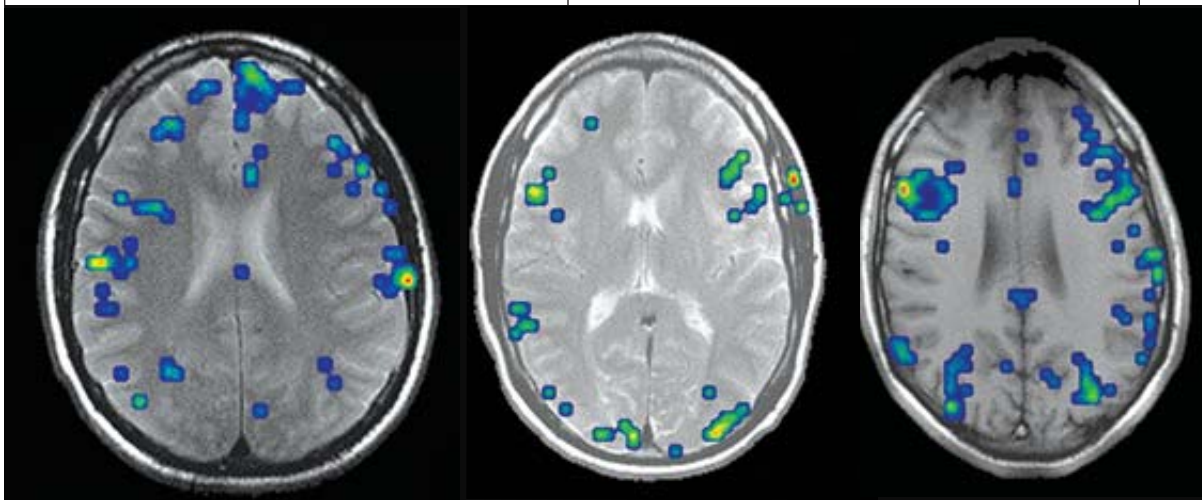
tal functions to particular brain regions. Critics feel that fMRI overlooks the networked or distributed nature of the brain's workings, emphasizing localized activity when it is the communication among regions that is most critical to mental function.

"This is a very gross technique," says critic Steven Faux, who heads the psychology department at Drake University. "It's like a blurry photo—better than no photo but still blurry, with real limitations that are too often overlooked. It's very easy to overextend [the value of] this technology."

Many fMRI practitioners seem bewildered that this powerful new tool has created controversy. "It is a huge surprise to me how big this issue has become," says Marcus E. Raichle, a Washington University neurologist who has re-

The 1970s also brought the first functional imaging technology—scans designed to show not just how the brain is structured but how it functions. Positron emission tomography (PET) measures increases in blood flow associated with neuronal activity, giving a sense of which neurons may be processing information. A subject is injected with radioactive elements that tag molecules such as glucose that are delivered to the brain by blood. The tags emit positrons and reveal the relative rates at which cells consume the glucose, a marker of which cells are active during mental processes. The scans are captivating, but there are a number of drawbacks. Subjects worry about taking in radioactive material; the process requires the better part of an hour for a scan; and the images provide a rather broad temporal resolution of 60 seconds (meaning it

Functional MRI scans of six people who took the same spatial memory test show how varied brain activation patterns can be. Scientists must design fMRI experiments carefully to avoid misleading conclusions.



searched brain scanning for more than two decades.

Vague Precision

Brain imaging began with an early 20th-century method called pneumoencephalography, a dangerous procedure in which the skull's cerebrospinal fluid was replaced with air to show the brain more clearly on x-ray. The angiograph, developed in the 1920s, produced improved results by capturing images of dyes injected into the bloodstream. (Angiography is still used to help diagnose and track blood vessel defects and some tumors.) These early methods showed only static structure rather than function. Computed axial tomography (CAT or CT) scans, developed in the 1970s, exploited x-ray technology and took static pictures, too, but with far greater detail.

takes that long to measure the blood flow to an area) and a spatial resolution of six to nine cubic millimeters—large for a nuanced understanding of what is happening.

In contrast, fMRI can scan a brain cross section in less than two seconds, enabling it to model most of the brain in one to two minutes. It can work at spatial resolutions as fine as two to three cubic millimeters, although in practice it usually collects information in voxels (a term that merges "volume" with "pixel") about two millimeters square and four to five millimeters long, about the size of a grain of rice. FMRI requires no injections, allowing more extensive scanning. In a typical study, a subject lies in a doughnut-shaped machine and is first scanned at rest with his eyes closed to provide a baseline reading. He is then scanned again while performing some mental task: identifying faces, threading a computerized

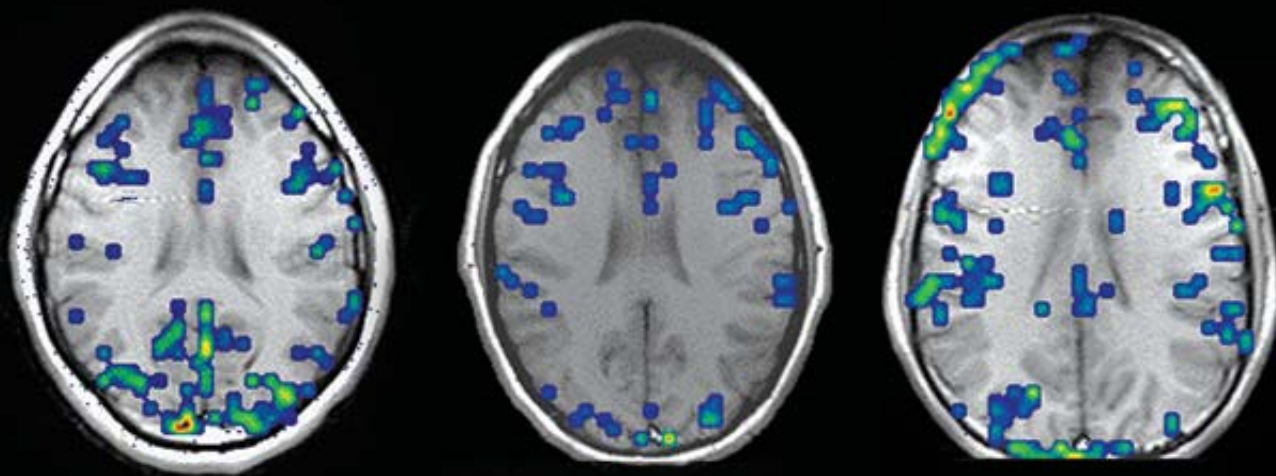
DAVID C. OSMON University of Wisconsin–Milwaukee

(The beautiful graphics fMRI produces imply much more precision than there actually is.)

maze, engaging in a role-playing game. In the most common technique, called BOLD (for blood oxygen level-dependent) fMRI, the machine measures increases in blood flow by spotting a change in magnetism that occurs when a blood surge raises the ratio of fresh, oxygenated hemoglobin to “used,” deoxygenated hemoglobin, which has a significantly different charge. The regions creating surges appear as brighter colors on the images, red changing to yellow as flow rises. Doubts about whether these increases correspond to actual neuronal activity have been answered by several studies tying blood flow di-

small group of neurons drawing little blood, or a thin network of neurons connecting large regions, may perform functions as crucial as a larger group elsewhere but either go undetected or show up as minor activity. Likewise, some neurons might operate more efficiently than others, consuming less blood. All these factors could mean that an fMRI image misrepresents actual neurodynamics.

Processing the scan’s gigabytes of raw data so that they become images introduces other caveats. Researchers must choose among and adjust many different algorithms to extract an accurate



rectly to neuron signaling, including recent animal models that used probes to match the firing of individual neurons to the heightened flow seen in fMRI scans.

Yet the link is decidedly rough. Abigail A. Baird, a Dartmouth College psychologist who uses fMRI to study brain changes during adolescence, puts it succinctly: “Hemodynamic response is a sloppy thing.” For starters, neuronal action takes milliseconds, whereas the blood surge follows by two to six seconds; a detected increase in blood flow therefore might be “feeding” more than one operation. In addition, because each voxel encompasses thousands of neurons, thousands or even millions may have to fire to significantly light up a region; it is as if an entire section of a stadium had to shout to be heard.

Meanwhile it is possible that in some cases a

image, compensating along the way for variations in skull and brain configuration, movement of subjects in the scanner, noise in the data, and so on. This “chain of inferences,” as a recent *Nature Neuroscience* article called it, offers much opportunity for error.

Finally, most fMRI studies use univariate processing, which critics say shortchanges the distributed nature of neurodynamics. The charges rise because univariate (literally “one variable”) algorithms consider the data coming in from each voxel during a scan as one sum, which makes it impossible to know how the activity in a particular voxel accrued (all at once, for instance, or in several pulses) or how it related sequentially with activity in other voxels. Univariate processing *does* see all the parts working—thus the multiple areas lit up in most images—but not in a way that shows how one area follows or

Functional MRI is still young and is being used as a first-survey tool of more complex mapping to come.

responds to another. This situation makes viewing an fMRI image something like listening to a string quartet by hearing (condensed into a single noise after the music has ended) only the total amount of sound each instrument produced during the piece, rather than hearing how the players accompany and respond to one another. Statistical methods known as multivariate analysis can break down each voxel's activity and analyze the interchanges among brain regions, but the complexity of those analyses has so far limited their use.

Obvious and Not So Obvious

For some, these vagaries and limitations make fMRI too rough an instrument for the more ambitious work for which it is being used. "The beautiful graphics fMRI produces imply much more precision than there actually is," says Drake University's Faux. "It's really a very gross, if not vague, physiological measurement that people are using to try to pin down some very complex behaviors. And in too many studies the authors way overinterpret the data. None of that advances the science."

Raichle says this damns an invaluable tool for practitioners' occasional improper use. "We have to remember we're studying the brain," Raichle says, "about which we know very little. Imaging lets us probe it to generate new hypotheses. Some of the probing will look silly in retrospect. But much of it is very productive."

The silly pursuits are not terribly hard to find. Consider, for instance, a study showing that men's amygdalas (which play a key role in generating emotion) light up when they view Ferraris. Others, as Faux says, recklessly overinterpret: a study of Democrats and Republicans watching videos of John Kerry and George W. Bush concluded that heightened activity in the subjects' emotion-sensitive amygdalas when they viewed the opposing candidate "suggest[ed] the volunteers were actively trying to dislike the opposition." Yet other studies suffer from major design failures, as did more than 30 that claimed to find physiological markers of ADHD in children diagnosed with the disorder—but failed to control for the effects of their subjects' Ritalin use.

Such work does not prove any fatal flaw in fMRI, Dartmouth's Baird says, but instead high-

lights the importance of using careful technique, solid study design and judicious interpretation. Baird, who likes to check her fMRI studies against similar research using other methods, likens fMRI interpretation to analyzing skid marks at an accident scene: "Someone who's done it often, who is careful and who collects a lot of other evidence will probably draw useful conclusions. Someone who's inexperienced or who doesn't check the whole scene will probably read them poorly."

Even serious, well-crafted studies can be undermined by subtle design failures. In a widely cited and publicized study of adolescent emotional responsiveness, for instance, Deborah Yurgelun-Todd of Harvard Medical School's McLean Hospital scanned adolescents as they characterized the expressions of fear-struck, middle-aged faces shown in black-and-white photographs. Compared with adults, adolescents viewing the images showed less activity in the frontal lobes, where much analysis and judgment occurs, and more in the amygdala. The adolescents also scored poorly in characterizing the expressions. Yurgelun-Todd told PBS's *Frontline* that the results suggested that "the teenager's brain may be responding with more of a gut reaction than an executive or thinking kind of response." But in a follow-up, Baird ran a similar experiment using color photographs of adolescent faces and found the adolescent subjects responded and scored much like adults. "They were simply more engaged by more contemporary photos in color," Baird says. "They did well if they cared."

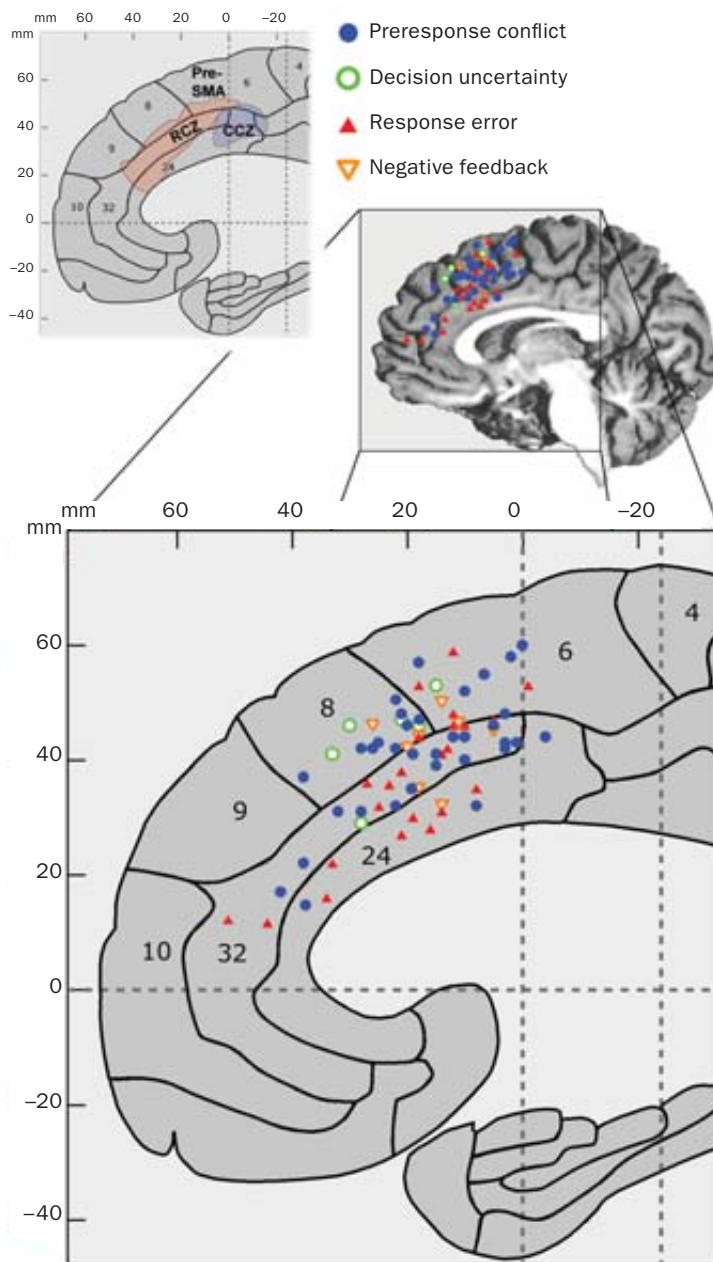
This tale highlights some of fMRI's most vexing nontechnical difficulties: the danger and ease with which a design flaw can corrupt results; the imagery's power to sway professionals, the media and the public despite those flaws; and the way results can reinforce conventional ideas, such as those regarding teen thinking and behavior. This last problem animates some of fMRI's most significant critiques. Some critics, including

(The Author)

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Find the Executive

Many fMRI studies have “pinpointed” the brain’s so-called executive function, believed to organize thoughts and planning, and declared it to be the cause of various mental deficiencies (*noted in key*). Yet an analysis by K. Richard Ridderinkhof of the University of Amsterdam of 38 such studies shows that determination of the executive function’s location (*colored icons, middle and bottom*) varied considerably across the medial frontal cortex (*colored regions, top*), notably in zones of the cingulate cortex (Pre-SMA, RCZ, CCZ). Critics also note that these regions may “light up” on many tests simply because the executive function underlies so many brain activities, providing little insight into the cause of a given deficit. (Numbers on schematics, such as 10 and 32, identify general anatomical zones.)



Faux and psychologist William R. Uttal, professor emeritus at the University of Michigan at Ann Arbor, argue that many of the cognitive functions under study in fMRI work are so abstract and vague that they denote little more than a conceptual nervous system. At the top of Faux’s list is the brain’s so-called executive function. “That’s a real favorite,” he says, “to measure the ‘central executive.’ Now—what is that?”

Many psychiatrists and neurologists agree that executive function is a real faculty, and im-

aging and physical studies indicate it arises from a network of regions in the prefrontal cortex and anterior cingulate cortex (a small location tucked between the two frontal lobes). The executive function organizes thoughts and gives people the ability to plan and carry out their resolutions. But brain experts are suspicious about how often executive function is cited as a factor in fMRI tests; the regions involved light up frequently. Too many researchers may too glibly conclude that executive function is therefore the

culprit, whereas its regions may just be lighting up because executive function underlies so many brain activities that it may pretty much always be “on.”

In part, critics such as Faux and Uttal are protesting the arbitrary nature of terms that are necessarily abstract; they are questioning judgment calls about the reality of an unseen thing. A scan is only a representation of activity. But fMRI proponents counter that everyone seems to accept when physicists and astronomers describe distant cosmological objects that are not seen at all but that are inferred from data. The same goes for the ultimate building blocks of matter. “You can’t see or measure subatomic particles directly,” notes John Darrell Van Horn, who directs operations at the fMRI Data Center at Dartmouth. “But they’re useful, well-supported mod-

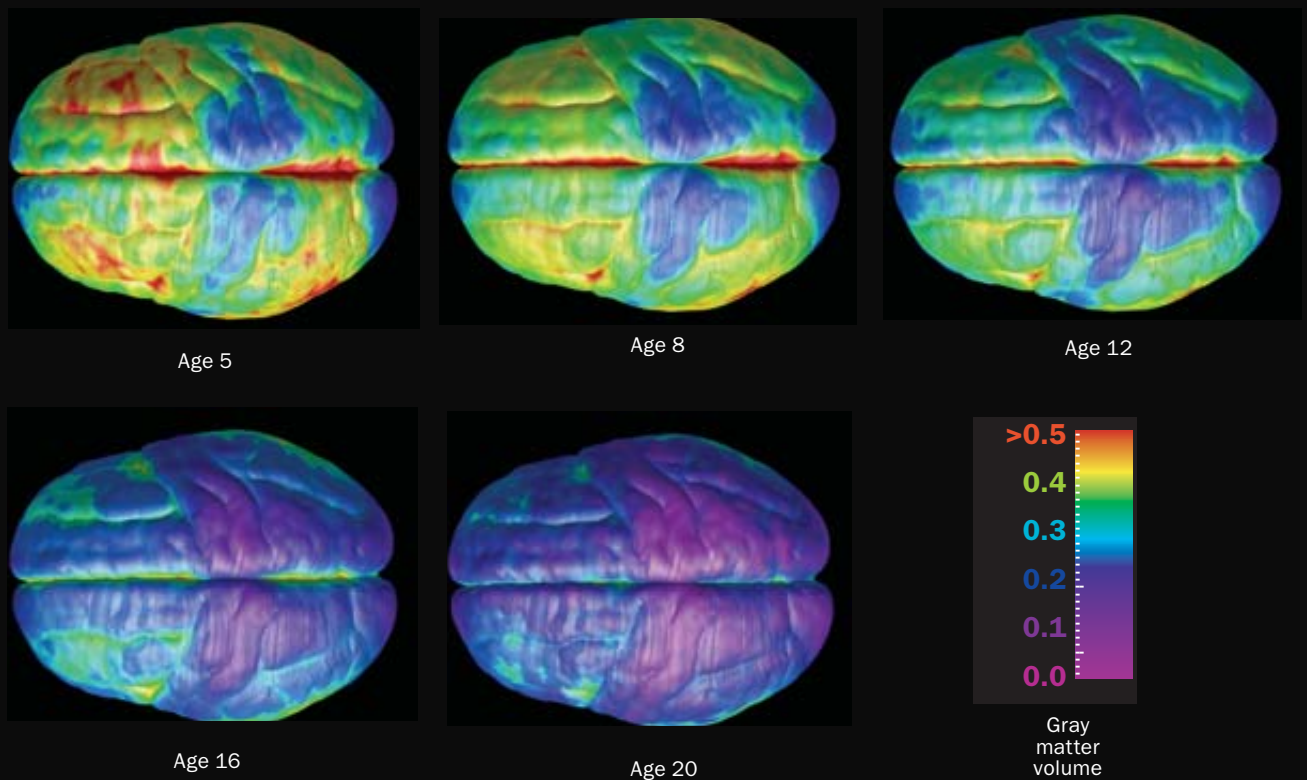
els we can refine based on experiment. I think many of these functions are quite similar.” Yet as Van Horn points out, the central executive concept pushes the limit for many, including him; he considers it more metaphor than model. Further evidence will be needed to resolve these fuzzy nomenclature issues.

A Wider View

It is not happenstance that fMRI controversies concern matters both conceptual and tangible. This duality is inherent in scientists’ attempts to connect the ephemeral mind to the corporeal brain. One basic concern is that fMRI is a new wrinkle on the old temptation to tie specific mental processes to particular brain regions.

Few researchers seriously believe that brain

Gray Areas



Functional MRI can map the brain’s composition with exquisite clarity. This sequence shows how gray matter is gradually replaced or overgrown with white matter between ages 5 and 21. A defense attorney could ostensibly use such information to ask that a teenager convicted of a violent crime not be sentenced as an adult since his cognitive capacity is not as fully developed.

IMAGES COURTESY OF PAUL THOMPSON, KIRALEE HAYASHI AND ARTHUR TOGA University of California, Los Angeles AND NITIN GOGTAY, JAY GIEDD AND JUDITH RAPOPORT National Institute of Mental Health

functions are so compartmentalized. As Raichle says, “No rational person would suggest there’s a single ‘emotion’ spot, for instance.” Yet most fMRI studies have indeed focused on how a given mental process activates certain areas. This has provoked the biting accusation that fMRI studies constitute “the new phrenology,” a modern version of the 19th-century practice of interpreting the bumps on a person’s skull as a map of his or her intelligence and character. Uttal has written an entire book about the subject [see “Further Reading,” below].

which object that person had been viewing. Expanding and refining such multivariate protocols should let fMRI reveal far more about how the brain’s regions work together.

Will such improvements end the controversies about fMRI and other brain imaging? Perhaps in part. More standardized processing protocols and peer review should reduce methodological blunders. And advances will most likely overcome technical concerns; researchers are already working on combining fMRI’s spatial acuity with the tighter temporal resolution of electro-

Most people are uncomfortable with having their ideas and feelings reduced to pixelated pictures of neurons.

This charge may be overstated. Most fMRI investigators seek not to localize brain function but to map the parts of the system that act in different combinations for different tasks. Although the very approach may suggest a localization mind-set, it may simply be that fMRI is still young as a technique and is being used as a first-survey tool of more complex mapping to come; it is only natural to plot a simple map of cities before delineating the intricate road systems that link them. Even when compared with those of just three years ago, fMRI studies today more often identify and discuss relations between several active brain regions. Someday fMRI may be able to show the brain’s true nature, which Raichle says is “like an orchestra,” with the different sections playing at various times, volumes and timbres depending on the effect needed, interacting in endless combinations to create an infinite variety of music.

What’s Next?

To hear that music more fully, current fMRI technology must advance. One key is to improve the multivariate algorithms that can track interactions among brain regions. Researchers such as James V. Haxby of Princeton University, David Cox of the Massachusetts Institute of Technology, Mona Spiridon of the University of Geneva in Switzerland and Christian Habeck of Columbia University have successfully used multivariate processing to reveal interactions among brain areas. Cox found that volunteers looking at different objects produced patterns so distinctive that he could quickly learn to examine a series of scans from a subject and correctly guess

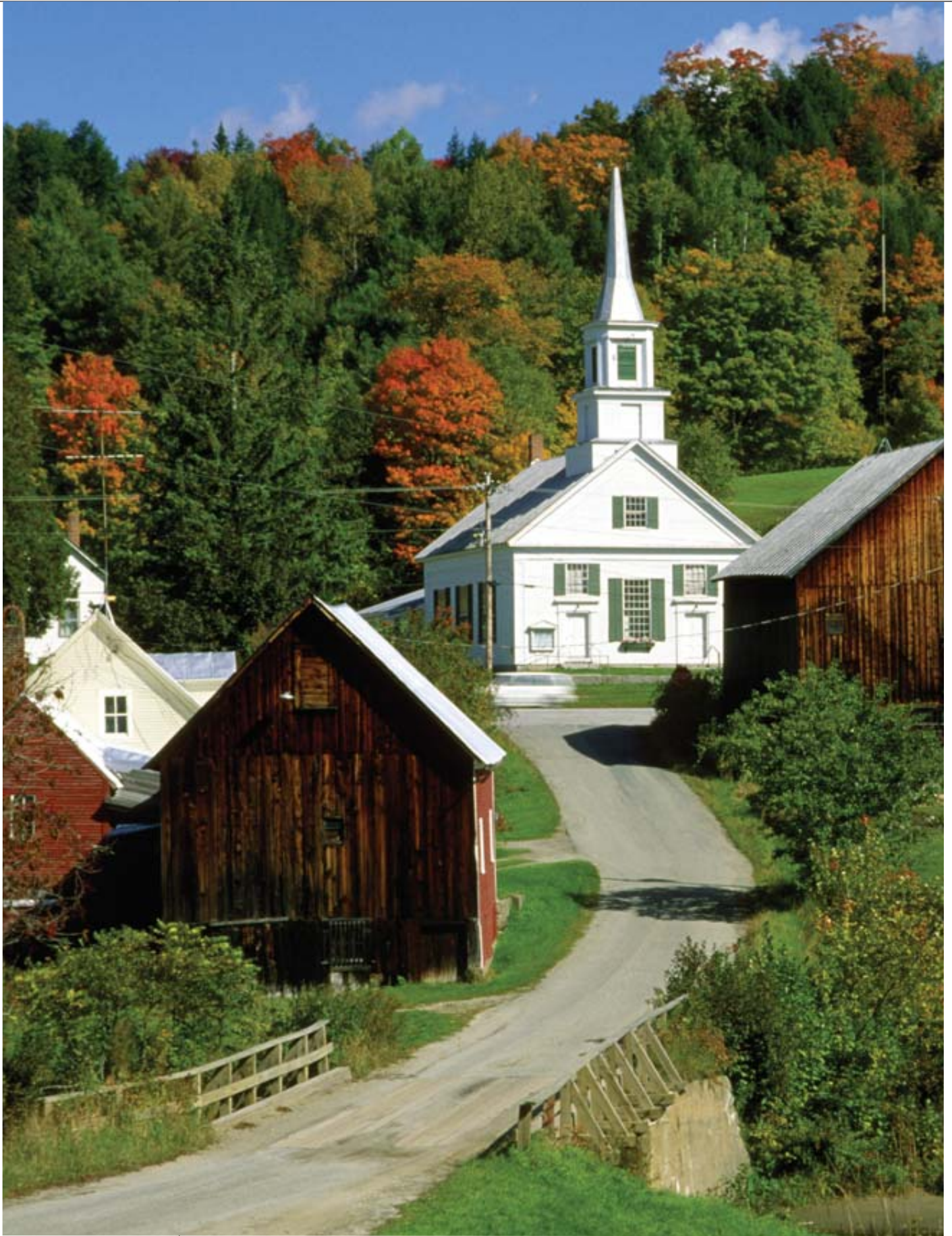
encephalography and magnetoencephalography, which measure neuronal activity by detecting, respectively, the minute electrical and magnetic activity that neurons produce. Such innovations, and others not yet foreseen, should someday measure neural activity with more spatial and temporal precision.

Such advances may or may not resolve the philosophical anxiety that brain imaging provokes. The attempt to identify the neural correlates of consciousness rouses the long insistence, first fully articulated by René Descartes, that our minds are more than our brains. We resist the notion of “the mind as meat,” as novelist Jonathan Franzen phrased it when contemplating his father’s Alzheimer’s disease. Most people are uncomfortable with having their ideas and feelings—what seem to be their very character and identity—reduced to pixelated pictures of neurons in action.

As technology makes it easier to bind the two, this metaphysical unease may only grow. Or perhaps we will get over it. As noted University of Iowa neuroscientist Antonio R. Damasio, who calls this resistance “Descartes’ error,” argues, we may eventually tie the complexities of thought and emotion to our neurons without any sense of loss.

(Further Reading)

- ▮ **A Measured Look at Neuronal Oxygen Consumption.** John E. W. Mayhew in *Science*, Vol. 299, pages 1023–1024; February 14, 2003.
- ▮ **The New Phrenology.** William R. Uttal. MIT Press, 2003.
- ▮ **Interpreting the BOLD Signal.** Nikos K. Logothetis and Brian A. Wandell in *Annual Review of Physiology*, Vol. 66, pages 735–769; March 2004.



Researchers are starting to pin down what déjà vu is and why it arises. But have you read this already? Maybe you just can't remember

STRANGELY Familiar

You're driving down the bustling main street of a picturesque little town you have never visited before. The traffic light turns red, you stop, and an old lady steps into the crosswalk from the left. All of a sudden you are overcome with a feeling that you have been here before—in the same car, at the same crosswalk, with the same

woman stepping off the curb in the same way. Yet by the time she reaches your front bumper, you realize the scene no longer matches quite so well with what you thought you were recalling. And you do know you have not been here previously. The familiarity is broken.

By Uwe Wolfradt



Various studies indicate that 50 to 90 percent of us can recall having had at least one such déjà vu incident in our lives. We experience a vague sense of having encountered a situation before, identical in every detail, even though we can't say when the first event took place. Usually the sensation lasts only a few seconds. Teens and young adults stumble on the dreamlike state more often than older adults, yet people of all ages experience déjà vu, especially when they are either fatigued or overly aware because of stress. A few people sense the inverse of déjà vu, called *jamaïs vu*. When they encounter a familiar person or place, they nonetheless insist they have never seen the individual or scene before.

The term “déjà vu”—French for “seen already”—may have first been used in 1876 by

French physician Émile Boirac. For much of the 20th century, psychiatrists espoused a Freudian-based explanation of déjà vu—that it is an attempt to recall suppressed memories. This “paramnesia” theory suggests that the original event was somehow linked to distress and was being suppressed from conscious recognition, no longer accessible to memory. Therefore, a similar occurrence later could not elicit clear recall yet would somehow “remind” the ego of the original event, creating an uneasy familiarity.

Many who have experienced déjà vu share the conviction that the phenomenon must arise from some mystical power or as a sign of a past life and reincarnation. They reason that because logical thought and clear perception reign immediately before and after an episode, some paranormal

force must be the only plausible explanation.

Scientists, unsatisfied with such conjecture, have long sought clues about the physical causes behind déjà vu, but investigation has proved elusive, because déjà vu never announces itself in advance. Scientists have been forced to rely mostly on the recollections of test subjects. But enough accounts have been examined to allow experts to start defining what déjà vu is and why it arises.

Not Hallucination

One place to start is to distinguish déjà vu from other unusual perceptual experiences. The scenes are not hallucinations, for example, which involve heightened awareness of visual, auditory

have forgotten—or, rather, cannot retrieve—is that when you were a young child, your grandparents had a cupboard just like this one in their home.

A related theory implies that we may perceive a person, place or event as familiar if at some earlier time in our lives we were exposed to just a partial aspect of the experience, even if it was within a different context. Perhaps, when you were young, your parents stopped at a flea market while on vacation and one vendor was selling old kitchen cupboards. Or perhaps you smell an odor that was also present at that flea market you attended as a child. A single element, only partially registered consciously, can trigger a feeling of fa-

A long-forgotten sight or smell can trigger familiarity by erroneously transferring itself to the present.

or other sensations triggered by internal brain imbalances, whether from mental illness or narcotics such as LSD. *Fausse reconnaissance*—“false recognition” or “false memory”—is not the same either; this condition often appears during a phase of schizophrenia and can drag on for hours.

Patients who suffer from temporal lobe epilepsy also have experiences that resemble déjà vu. For example, a young male patient in Japan was convinced that he was constantly reliving several years of his life and marriage. Desperate to escape the cycle, he repeatedly tried to commit suicide. But this phenomenon differs from déjà vu in a distinct way: a person with temporal lobe epilepsy firmly believes his experience is identical to a past situation, whereas during déjà vu a person quickly recognizes it as illusionary and unreasonable.

A survey we conducted several years ago with more than 220 students at the Martin Luther University of Halle-Wittenberg in Germany showed that after they had experienced déjà vu, 80 percent of the respondents were able to recall a past event that was indeed similar in nature—an event they had forgotten. In line with this study, cognitive psychologists have shifted their attention to another unconscious process, that which is responsible for so-called implicit, or nondeclarative, memories. These are artifacts that we have long forgotten and do not retrieve consciously, although they have not been erased from our neural networks. Consider seeing an old cupboard at a flea market, and suddenly it seems strangely familiar, as does the act of viewing it. What you may

miliarity by erroneously transferring itself to the present setting.

Insufficient Attention

These assumptions, which are founded on the unconscious processing of information, ultimately place responsibility for déjà vu on gaps in our attention system. Let's say you're driving down a hectic street and are concentrating on the flow of traffic. An old lady is standing on the sidewalk; you see her in your peripheral vision, but you are not really consciously aware of her. A second later you have to stop at a traffic light. Now you have the time to look around. As you glance at the old woman, stepping with difficulty off the curb into the crosswalk, leaning heavily on her cane, she suddenly seems familiar, even though you don't believe you have ever seen her before and you know you have not been at this intersection before. The first image of the woman, perceived during your distracted state, was immediately followed by a second image when you were fully alert. Because the information was received without conscious attention only shortly before, it is now falsely interpreted as a long-term memory.

Studies on subliminal awareness provide empirical support for this theory. In 1989 a team led

(The Author)

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by psychologist Larry L. Jacoby, now at Washington University, gathered test subjects in a room and very briefly projected onto a screen before them a single word, flashed so quickly that it was impossible for the viewers to consciously register it as a word, yet the visual imprint was recognized somewhere in the visual centers of the brain. Later on, when Jacoby projected the same image again for a longer time, the participants repeatedly claimed to have seen the word before. The unconscious processing of subliminal stimuli allows for similar stimuli perceived later to be processed at a much faster rate—a procedure known as priming that has been widely researched since.

Priming and other attention traits seem to fit well with the general circumstances involving déjà vu. In the early 1900s Gerard Heymans, founder

of psychology in the Netherlands, followed 42 students for six months. They filled out a short questionnaire immediately after any déjà vu episode. Heymans concluded that persons subject to mood swings or periods of apathy, as well as those with irregular work patterns, were more prone to such illusions. Other observers have reported that they were more prone to déjà vu experiences when they felt extreme fatigue and a higher stress load.

And in an independent study carried out recently at Halle-Wittenberg, 46 percent of students stated that they were in a relaxed mental state when déjà vu had appeared, with one third describing their state as happy. It seems that whereas déjà vu may be triggered during times of peak tension when one is overly alert, it may be even more likely when one becomes tired and attention starts

to wane. New research also indicates that déjà vu may be more likely in people who can readily immerse themselves in fantasies and daydreams.

Delayed Vision

Understanding the neurological basis for déjà vu would certainly help scientists pin down its trigger, but neural connections are only partially understood. For a long time, one popular theory held that delayed neurological transmission was responsible. When we perceive, pieces of information from different neuronal paths enter the processing centers of the cerebrum and must, of course, blend together to consistently produce a uniform impression. It would make sense that any

states and déjà vu experiences during the stimulation. Similar accounts also came from a 1994 paper by Jean Bancaud and his team at the Paul Broca Center in Paris: stimulating the lateral or medial temporal lobes occasionally triggered dreamlike trances, including déjà vu.

Memory without Memories

Although questions exist about how well such artificially induced déjà vu episodes resemble those that occur naturally, the findings are intriguing. After all, neuroscientists have proved that the medial temporal lobe is directly involved in our declarative, conscious memory. The hippocampus, which helps to register perceptual events as epi-

Understanding déjà vu could explain how the brain succeeds in producing a coherent likeness of reality.

delay in some aspect of transmission could be muddled and set off déjà vu.

In 1963 Robert Efron, then at the Veterans Administration Hospital in Boston, tested this general notion. His experiments led him to conclude that the temporal lobe of the brain's left hemisphere was responsible for the punctual sorting of incoming data. He also found that this location received signals coming over visual pathways twice, within milliseconds of one another—once directly and once via a normal detour through the right hemisphere. If, for some reason, a delay were to occur in the detoured transmission, the left temporal lobe would register a time lapse on the second arrival and could interpret the visual scene as having already happened.

Efron's theory of double perception has yet to be refuted or verified. But it appears that the temporal lobes play a decisive role. Some patients who have suffered damage to this area report frequent déjà vu experiences. So do those who have temporal lobe epilepsy, characterized by seizures in the temporal lobes that produce vivid hallucinations of what seem to be memories. Some researchers therefore think that déjà vu is nothing more than a small circuit failure within the brain.

Observations during neurosurgery also point to the temporal lobes. The first came from Wilder Penfield, a neurosurgeon at the Montreal Neurological Institute, who in the 1950s conducted now famous experiments in which he electrically stimulated the temporal lobes of patients during open-brain surgery. Subjects often reported dreamlike

sodes and which later makes it possible for our minds to recall them as if we were watching a movie, is also found in this section of the brain.

Also located in the medial temporal lobe is the parahippocampal gyrus, the rhinal cortex and the amygdala, all of which are heavily involved in memory. In 1997 John D. E. Gabrieli and his colleagues at Stanford University established that the hippocampus makes possible the conscious recollection of events and that the parahippocampal gyrus distinguishes between familiar and unfamiliar stimuli—and does so without having to retrieve a concrete episode from our memories.

Many regions of the brain may ultimately be involved in producing déjà vu. The emotions this experience elicits, triggered by a sense of alienation from oneself and one's surroundings as well as the loss of all sense of time, indicate that a complex process is at work. When déjà vu occurs, we doubt reality for a moment. For neuroscientists, these small errors offer invaluable insight into the workings of our consciousness. Further research on the déjà vu phenomenon will help explain not only how we manage to deceive our memory but perhaps how the brain ultimately succeeds in producing a coherent likeness of reality.

(Further Reading)

- ▮ **Déjà Vu: Possible Parahippocampal Mechanisms.** Josef Spatt in *Journal of Neuropsychiatry and Clinical Neuroscience*, Vol. 14, pages 6–10; February 2002.
- ▮ **A Review of the Déjà Vu Experience.** A. S. Brown in *Psychological Bulletin*, Vol. 129, pages 394–413; 2003.

A photograph of a man floating on his back in clear, shallow blue water. His arms are outstretched upwards, and his head is tilted back. The water's surface is rippled, creating a pattern of light and shadow over his body. The overall tone is serene and aquatic.

D R O W

He knows he is suffocating at the bottom of the pool,
but he just doesn't feel like swimming right now

DROWNING MR. M

The summer heat is oppressive. Mr. M, seated beside his pool, looks at the cold water. "What could be better than a refreshing dip?" he thinks. He dives headfirst into the water and takes a couple of powerful strokes. Then, suddenly, he stops. He exhales, sinks to the bottom and simply stares straight ahead. "I'm drowning," he realizes, strangely unperturbed. He knows that a few strong kicks would bring him back to the surface. But he can't quite bring himself to do so.

As luck would have it, his daughter has been watching from inside the house. She runs out and dives into the pool to save him. The sight of his daughter shakes Mr. M from his apathy, and just as she reaches him he propels himself upward, breaking the surface and gasping for air. Later he tells his family, "I don't know what was wrong with me. I just didn't want to swim anymore."

What was happening in Mr. M's brain as he came within seconds of drowning? How could he so abruptly lose all desire to act, even to save his own life?

Neurologist Dominique Laplane first described such bizarre behavior in 1981. A doctor at the Hôpital de la Salpêtrière in Paris at the time, Laplane called the phenomenon "PAP syndrome," from the French *perte d'auto-activation psychique*, or "loss of psychic autoactivation." (Subsequently, other experts have also labeled the condition "loss of mental self-activation" or "athymhormic syndrome.") Since then, scientists have come to learn that damage to certain areas of the brain causes patients to lose their motivation as well as their ability to reach decisions. It is as if they have become mere spectators to their own lives, no longer actively participating. By examining the brains of these patients, researchers are finding initial clues to how willfulness arises in all of us.

BY PATRICK VERSTICHEL AND PASCALE LARROUY

Yes, I'm Starving

Within only a few weeks after the pool incident, Mr. M's personality underwent a drastic change. The normally active and energetic man became increasingly passive and apathetic. He spent entire days in bed yet felt neither boredom nor impatience. His family had to remind him constantly to carry out the most basic activities: "Come to dinner! Get dressed! Take a shower!"

Such complete lack of motivation is the most obvious symptom of PAP syndrome. If left to their own devices, patients will remain in bed or on the couch for hours or even days, doing nothing but lying there awake or asleep. They do not make any plans for the future. Hobbies no longer interest them. Their utter spiritlessness extends even to fundamental needs; Mr. M's wife said her husband would have starved to death had she not intervened. Yet he never complained of hunger.

Incredibly, PAP patients do experience hunger and pain. They simply lack the will to react. Such inaction injured one 18-year-old woman examined at the Hôpital de la Timone in Marseille, France. During a visit to the beach, her parents had left her sitting in the shade while they went on an afternoon trek. As the sun moved across the sky, the woman became exposed to the scorching rays and remained there for several hours. She felt the heat but did not make any effort to take cover and suffered second-degree burns.

PAP patients require external stimuli to spur them on. Once they are encouraged, however, they can carry out complex activities as well as they once had. The patients do not often speak, but when asked direct questions they offer rational answers about their strange behavior. PAP patients also pass intelligence and memory tests, as long as the examiner keeps urging them to continue. Unfortunately, the effects of external stimuli are only temporary. Soon enough, patients revert back to silence and apathy.

What is going on in these patients' heads? What are they thinking? PAP patients often respond, "Nothing." Is that even possible—to be fully awake yet not thinking about anything for hours on end? Evidently so: patients generally describe their mental state as "empty."

Surprisingly, they do not suffer psychologi-

cally from this inertness. They are almost incapable of experiencing emotions. A once fun-loving, now fully apathetic 70-year-old teacher described her reaction to the death of her nephew this way: "It's quite tragic. Before, I would have been totally devastated. But now, it's really not such a big deal." Although patients recognize tragic or joyous occasions as being such, they can no longer sense or express sadness or joy. Their "feelings," Laplane notes, are more of an intellectual nature than actual feelings.

Some patients develop obsessive behavioral disorders—senseless, repetitive activities such as repeatedly turning a light or the television on and off. While lying in bed, one patient could not stop himself from continuously counting the ceiling tiles. At times patients irritate people around them with verbal tics, such as constant use of profane words. The cause of these pointless patterns is not known, but perhaps the brain is attempting to fill the mental emptiness.

Motivation Switched Off

PAP syndrome brings to light an important question facing brain researchers today: How is motivation created to trigger behavior? In PAP patients such as Mr. M, motivational mechanisms seem completely inactive. The patients ignore internal signals necessary to survival as well as social, moral and civil obligations—the so-called higher aspects of motivation. In addition, they are unable to see themselves in any kind of future scenario and cannot comprehend the consequences of their inactions.

Using processes such as magnetic resonance imaging (MRI), researchers have recently begun to unveil the secrets behind this condition. So far in every case of PAP syndrome, an acute illness has been found that affects some area of the basal ganglia deep inside the brain. The ailments have varied from lack of oxygen caused by clogged blood vessels to carbon monoxide poisoning. Two large tumors were discovered in Mr. M's brain; the larger of the two, in the left hemisphere, was putting pressure on his basal ganglia.

The basal ganglia are long, thin structures that have strong connections to the pathways that bring information from sensory organs to the motor regions (which tell muscles to move). The basal ganglia also connect to the frontal lobe, where problem solving, planning and decision making are done. MRI studies show that in many PAP patients the frontal lobe is not functioning properly. When working on thought exercises, this area is considerably less active than it is in healthy subjects.

(The Authors)

PATRICK VERSTICHEL and **PASCALE LARROUY** have studied several PAP patients together. Verstichel is a neurologist at the Centre Hospitalier Intercommunal de Créteil in France. Larrouy wrote her doctoral dissertation on brain pathways that might cause PAP syndrome.

When Motivation Dies

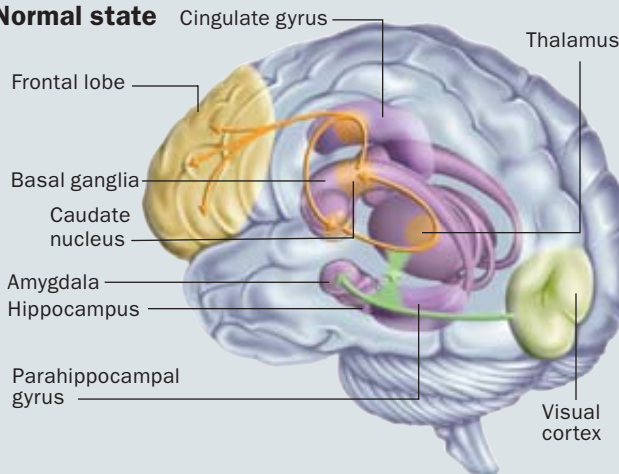
A special neural network called the limbic loop (*left*) drives our decisions about whether or not to act on external and internal stimuli. Sensory information travels to various parts of the brain's limbic system (*purple*). Here the data are evaluated on an emotional level, and assessments (*orange*) move through the basal ganglia to the cingulate gyrus. From there, assessments land in the frontal lobe, which makes a determination. The basal ganglia structures act as an on/off switch—they determine if the frontal lobe is to be activated or not.

In patients with PAP syndrome (*right*), the limbic loop is damaged: the basal ganglia do not ferry information

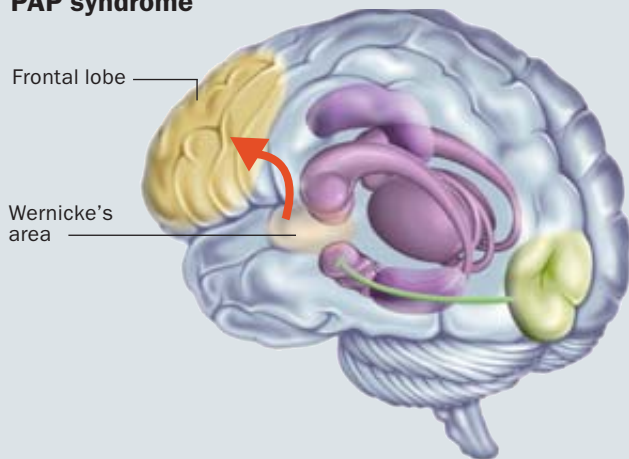
through to the frontal lobe. Without input, it cannot make a decision to act. The various stimuli carry no emotional importance, so the patient's motivation or will is not activated. Patients can act when spoken to directly; language information jumps from Wernicke's area (one of the brain's language centers) directly to the frontal lobe (*red arrow*), bypassing the limbic loop.

In people suffering from depression, the caudate nucleus does not function properly, which dampens responses in the frontal lobe. For some schizophrenics, abnormalities in receptors that respond to the neurotransmitter dopamine decrease the limbic loop's effectiveness.

Normal state



PAP syndrome



People who have experienced other kinds of damage to just the frontal lobe have symptoms similar to those of PAP patients. They, too, are apathetic and fail to organize activities for the future. Together the basal ganglia and frontal lobe steer motivation and therefore an individual's will. The basal ganglia determine whether or not the frontal lobe should be activated. They act as a "switch" that can turn on or off our desire to act.

But if the connection between those structures has been impaired, why do PAP patients still act on external stimuli such as a daughter's face or a wife's command? Because other pathways can also affect motivation. For example, the frontal lobe can be directly activated by certain areas of the cerebral cortex, including the language centers. When Mr. M's family members speak to him, the language stimuli travel not only to the limbic system but also to the language areas in the frontal lobe. Having been activated in this way, the frontal lobe can make a determination and prompt Mr. M to eat or take a shower. For a moment, he can reconnect with his normal life, thanks to the intervention of a personal prompter.

Then it is back to the couch. Or the bed.

PAP syndrome is relatively rare, so little research has been done on how to aid these hapless people. It is unclear whether certain psychotropic drugs can help. Although to observers a victim's symptoms may seem to mirror depression, most patients, such as Mr. M, do not seem particularly upset about their apathy, so they may not be depressed in the clinical sense or respond to common antidepressants. And it may be hard to help patients whose symptoms have been brought on by a brain-damaging event such as a stroke until medicine finds a way to compensate for such damage. More research is needed into ways to relieve PAP symptoms. As is sometimes the unfortunate case with people who suffer psychiatric ills, medicine has little to offer, and families or friends of PAP patients may have little choice but to constantly prod their loved ones along.

(Further Reading)

▮ **Affective Disorders Due to the Loss of Mental Self-Activation: Comparison with Athymhormia.** D. Laplane and B. Dubois in *Review of Neurology*, Vol. 154, No. 1, pages 35–39; January 1998.

ESSAY



LINDA BLECK Images.com/Corbis

Neuroscience and the LAW

**IF SCIENTISTS CAN PROVE THAT THE BRAIN DETERMINES
THE MIND, LAWYERS COULD CONVINCE JURIES THAT
DEFENDANTS MAY NOT BE RESPONSIBLE FOR THEIR CRIMES**

BY MICHAEL S. GAZZANIGA AND MEGAN S. STEVEN

Imagine you are a juror for a horrific murder case. Harry is the defendant. You sit down with 11 of your peers—people who may not be up on the latest scientific understanding about human behavior. Most of the jurors have never heard the word “neuroscience” nor given a moment’s thought to the concept of “free will.” And you know that most jurors have little patience for criminal-defense arguments based on such notions as “temporary insanity.” The jurors are there to determine whether Harry committed the crime, and if they decide he did, they will deliver their verdict without regret. But have they considered whether Harry acted freely or as an inevitable consequence of his brain and his past experiences?



Defense lawyers are looking for that **one pixel** in their client's brain scan that shows a malfunction.

Although advances in neuroscience continue at a rapid pace, their ethical and legal implications are only beginning to be taken into account. The link between the brain and behavior is much closer than the link between genes and behavior, yet the public debate about the legal implications of genetic findings far outweighs that given to brain research.

Progress in neuroscience and technology raises numerous issues with respect to the core constructs of law, such as competency to stand trial, the genesis of violent behavior and the determination of whether witnesses are lying [see “The New Lie Detectors,” by Laurence R. Tancredi, on page 46]. For example, knowing that a brain deficiency predisposes certain people to violence would present a host of controversial questions, including whether we might “mark” these people for surveillance by authorities; whether preemptive treatment of these people is desirable; whether juries are likely to discriminate against them; and whether society might change how it punishes and rehabilitates such people who are convicted of crimes. How far along are we, today, in being able to make such determinations?

Free Will vs. Free Won't

Perhaps the most fundamental implication of 21st-century brain science is that a way may exist to evaluate free will. The logic goes like this: The brain determines the mind, and the brain is subject to all the rules of the physical world. The physical world is determined, so our brains must also be determined. If so, then we must ask: Are the thoughts that arise from the brain also deter-

mined? Is the free will we seem to experience just an illusion? And if free will is an illusion, must we revise our conception of what it means to be personally responsible for our actions?

This conjecture has haunted philosophers for decades. But with new imaging tools that show the human brain in action, these questions are being reexamined by neuroscientists and, increasingly, the legal world. Defense lawyers are looking for that one pixel in their client's brain scan that shows an abnormality—some sort of malfunction that would allow them to argue: “Harry didn't do it. His brain did it. Harry is not responsible for his actions.” [For more on the relative accuracy of such scans, see “Fact or Phrenology?” by David Dobbs, on page 24.]

At the same time, we must realize that even if the causation of an act (criminal or otherwise) is explainable in terms of brain function, that does not mean that the person who carries out the act is exculpable. Although brains can be viewed as more or less automatic devices, like clocks, we as people seem free to choose our own destiny. Is there a way to settle this dilemma?

A first step was taken in the 1980s by Benjamin Libet, now emeritus professor of physiology at the University of California at San Francisco. If the brain carries out its work before one becomes consciously aware of a thought, as most neuroscientists now accept as true, it would appear that the brain enables the mind. This idea underlies the neuroscience of determinism. Libet measured brain activity during voluntary hand movements. He found that between 500 and 1,000 milliseconds before we actually move our hand there is a wave of brain activity, called the readiness potential. Libet set out to determine the moment, somewhere in that 500 to 1,000 milliseconds, when we make the actual conscious decision to move our hand.

Libet found that the time between the onset

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of the readiness potential and the moment of conscious decision making was about 300 milliseconds. If the readiness potential of the brain is initiated before we are aware of making the decision to move our hand, then it would appear that our brains know our decisions before we become conscious of them.

This kind of evidence seems to indicate that free will is an illusion. But Libet argued that because the time from the onset of the readiness potential to the actual hand movement is about 500 milliseconds, and it takes 50 to 100 milliseconds for the neural signal to travel from the brain to the hand to actually make it move, then there are 100 milliseconds left for the conscious self to either act on the unconscious decision or veto it. That, he said, is where free will arises—in the vetoing power. Neuroscientist Vilayanur S. Ramachandran of the University of California at San Diego, in an argument similar to 17th-century English philosopher John Locke's theory of free will, suggests that our conscious minds may not have free will but do have "free won't."

Resisting Violent Tendencies

Many other experiments show that our brain gets things done before we know about them. But what does this mean for real-life problems of free will, such as violent behavior? Is there a way to use current scientific knowledge to argue for reduced culpability under the law?

Evidence from patients with brain lesions confirms that the prefrontal cortex plays a critical role in social behavior. And psychological exams indicate that people who repeatedly commit violent crimes often have antisocial personality disorder (APD). It would therefore be interesting to know if criminals with APD, who demonstrate abnormal social behavior similar to that of patients with prefrontal lobe damage, also have abnormalities in the prefrontal areas of the brain. To address this question, Adrian Raine, a psy-

chology professor at the University of Southern California, and his colleagues imaged the brains of 21 people with APD and compared them with the brains of healthy subjects and other controls. They found that people with APD had a reduced volume of gray matter and a reduced amount of neural activity in the prefrontal areas as compared with the controls. This finding indicates that there is a structural difference between the brains of criminals with APD and the brains of the normal population. The outcome also suggests that a volume difference in gray matter in that area of the brain may lead to a functional difference in social behavior.

In 2002 Antonia S. New, associate professor of psychiatry at the Mount Sinai School of Medicine, looked at a specific characteristic of APD—impulsive aggression. Using positron emission tomography, her team monitored the metabolic activity of the brain in response to an excitatory chemical called m-CPP in people with impulsive aggression and in healthy, nonaggressive controls. M-CPP normally activates the anterior cingulate (a frontal area of the brain known to be involved in inhibition) and deactivates the posterior cingulate. The opposite was found to be true for people with impulsive aggression: the anterior cingulate was deactivated, and the posterior cingulate was activated. The investigators concluded that people with impulsive aggression have less activation of inhibitory regions and that this may contribute to their difficulty in modulating aggression.

If findings such as these are true, it is still possible that certain violent people do not inhibit their impulses even though they *could* inhibit them—and therefore should be held responsible for their actions. Future research will be needed to de-

Should people who have a deficiency that causes **impulsive aggression** be "marked" for surveillance?



termine how much prefrontal damage is necessary, or to what degree the gray matter is reduced, for the cessation of inhibitory function and thus perhaps for the mitigation of responsibility.

Neuroscientists must realize, however, that for any given brain state, the correlation of non-violent behavior could be just as high as the correlation of violent behavior. For example, most patients who suffer from lesions involving the inferior orbital frontal lobe (in the prefrontal cortex) do not exhibit antisocial behavior of the sort that would be noticed by the law. Even though a patient's wife, say, might sense changes in her

husband's behavior, the man is still constrained by all the other forces in society, and the frequency of his abnormal behavior is no different than would be seen in the normal population.

The same view is true for people with schizophrenia, a disease marked by disassociation between intellect and emotions and by difficulty controlling moods and actions. The rate of aggressive criminal behavior is not greater among schizophrenics than it is among the normal population. Because people with lesions in the inferior orbital frontal lobe or with schizophrenia are no more likely to commit violent crimes than

The New Lie Detectors

BY LAURENCE R. TANCREDI

The traditional lie detector, the polygraph, has existed for many years. It relies on physiological reactions—increased heart rate, respiration, blood pressure and sweating—to indicate that a person being questioned is fearful of getting caught and is therefore lying. Although this machine has been used in criminal investigations, critics insist it can easily be defeated. Some people are very good at controlling their physiological responses. Others secretly invoke alternative sensations at the same time, which can confuse the polygraph. And simple fear of a false reading can cause reactions in an honest person's body chemistry that register as a false response. New brain-imaging techniques have reawakened interest in lie detection.

Near-infrared brain scan is a test of blood flow devised by Britton Chance, a biophysicist at the University of Pennsylvania. A headband containing near-infrared light emitters and detectors is placed on the subject's head, which reputedly senses changes in the prefrontal cortex, the site of decision making that is also stimulated by deception. According to Chance, the sen-

sors can detect changes that occur when a person makes a decision to lie—before the lie is actually articulated. Subjects are given a series of questions, some to be answered truthfully, others not, to chart the changes that occur. Although the device is still in development, Chance claims it will soon be capable of detecting covert activity in the prefrontal lobe.

Thermal imaging uses a heat-sensitive camera to detect increased blood flow around the eyes. Some scientists claim that when people lie, their eyes give off more heat than when they are telling the truth. This technique is in the early phase of development, and how accurate it may be is still an open question.

Functional magnetic resonance imaging (fMRI) is also being investigated. Daniel D. Langleben of the University of Pennsylvania recently studied 18 volunteers who were given certain playing cards. The subjects were then placed in an fMRI scanner. A computer present-

ed them with images of specific cards and asked them if they had those cards in their possession. When the subjects lied, their anterior cingulate cortex and superior frontal gyrus lit up more than when they told the truth. The anterior cingulate cortex, which has connections to



Old wire lie detector could be replaced by MRI.

COLIN ANDERSON/Getty Images

unaffected people, it seems that merely having one of these brain disorders is not enough to remove responsibility.

Automatic Brains, Interpretive Minds

Although mechanistic descriptions of how the physical brain carries out behavior have added fuel to the general idea of determinism, experts have argued that the concept of free will can coexist with determinism.

In 1954 noted English scientist and philosopher Alfred J. Ayer put forth a theory of “soft determinism.” He argued, as Scottish moral phi-

losopher David Hume had two centuries earlier, that even in a deterministic world, a person can still act freely. Ayer distinguished between free actions and constrained actions. Free actions are those that are caused by internal sources—by one’s own will (unless one is suffering from a disorder). Constrained actions are those that are caused by external sources—for example, by someone or something forcing you physically or mentally to perform an action,



the limbic system and the prefrontal cortex, is involved with emotional processing, decision making and conflict resolution. It seems to be frequently activated when a lie is being told.

Yet the anterior cingulate cortex is also involved with decision making in general, which is a confounding consideration. A subject may activate this region from mere anxiety about the lie detection event. Yet it appears that telling the truth does not create a distinctive brain print, just diffuse activity. More research must be conducted to assure that the evaluations of fMRI patterns are highly specific to lying.

Refinements of fMRI will probably be made so that information flowing between various brain regions could be traced, giving more insight into what the test subject is feeling. Functional MRI could also be linked with transcranial magnetic stimulation to produce a powerful lie detection system. The magnetic apparatus could block out or enhance activity from select parts of the brain, in effect eliminating interference in the fMRI signal and improving the accuracy of detection in critical brain regions. Using both technologies together could also create greater sensitivity to lies that are camouflaged with confounding thoughts invoked by the subject.

Brain-fingerprinting results have already been admitted into evidence in one case—a reexamination of an Iowa murder conviction—even though the technique has not gained wide acceptance in the scientific community. In this approach, developed by Brain Fingerprinting Laboratories, a subject wears a helmet of electrodes, creating an electroencephalogram (EEG) that records changes in

electrical potentials in the brain. The subject is presented with words, phrases or pictures while the EEG records her brain-wave activity. As with polygraphs, an investigator presents information that ostensibly only the offender would know. If the suspect knows the information but lies, a specific brain wave known as P300 is elicited. The P300 pattern is activated when the brain recognizes information (or a familiar object) as significant or surprising. The goal is to determine if the subject has the information stored in her brain even though she denies knowing it.

Lawrence A. Farwell, the inventor of brain fingerprinting, claims an accuracy of nearly 100 percent, but there are several problems. First, the presence of drugs and alcohol can adversely affect the reception and storage of information. Second, the investigator has to have detailed information that only the participant would know, requiring much investigation; FBI and police reports are not so detailed. Brain fingerprinting therefore will most likely prove significantly useful in situations in which unique factual information is available to investigators. Furthermore, with advances in behavioral genetics, it might be possible in the long term to correlate gene profiles with brain-fingerprinting waves. That could enhance the statistical validity of the test results by factoring out confounding conditions such as anxiety or fear and factoring in biological conditions such as psychopathy that are known to be highly associated with antisocial behavior.

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as in hypnosis or in disorders such as kleptomania. When someone performs a free action to do A, he or she could have done B. When someone makes a constrained action to do A, he or she could have done only A.

Ayer argued that actions are free as long as they are not constrained. Free actions are not dependent on the existence of a cause but on the source of the cause. Although Ayer did not explicitly discuss the brain's role, one could make the analogy that those actions—and indeed those wills—that are caused by a disease-free brain are not constrained, even though they may be determined. In this way, the brain is determined, but the person is free.

With each passing decade, the world knows more about the mechanistic action of the nervous system and how it produces perceptual, attentional, and mnemonic functions and decisions. Yet there is still much to learn about how the brain enables the mind.

We recently attended a conference at which more than 80 leading scientists presented their findings on this very subject. It became obvious that the central question remains not only unanswered but unexamined. The brain scientists who are addressing issues of human cognition are illuminating which brain systems correlate with particular measurable human behaviors. For example, a series of studies might investigate which areas of the visual system become activated when a person attends to a particular visual stimulus.

Although these correlations are of interest, the question of how the brain knows whether, when and how to increase the activity of a particular neuronal system remains unknown. Overall, modern studies always seem to leave room for the metaphorical ho-

munculus, the little ghost in the machine that directs all brain traffic. It is common in neurology circles to hear the phrase “top-down versus bottom-up processes”—processes driven by feedback from “higher” areas of the brain rather than direct input from the sensory stimuli—but the fact is that no one knows anything about the “top” in “top-down.” This is a major problem of cognitive neuroscience today, and we hope that it will soon become the subject of research.

Changing the Law

For now, we must operate with what we do know about the brain—and how that can influence the law. To address this, we must consider the current legal system's view of human decision making.

Under our legal system, a crime has two defining elements: the *actus reus*, or proscribed act, and the *mens rea*, or guilty mind. In order for Harry to go to prison for murder, both elements have to be proven beyond a reasonable doubt. The courts and the legal system typically work hard to determine the agency of the crime. Where they want help from neuroscience is on whether or not Harry should be held “personally responsible.” Did Harry do it, or did his brain? This is where the slippery slope begins. Our argument is that neuroscience can offer very little to the understanding of responsibility. Responsibility is a human construct, and no pixel on a brain scan will ever be able to show culpability or not.

In practice, legal authorities have had great difficulty crafting standards to divide the responsible from the not responsible. For example, the rules for a finding of legal insanity that have existed in various forms for more than 150 years are all lacking. Experts for the defense and prosecution argue different points from the same data. What they would like, instead, is for neuroscience to come to the rescue.

But the crux of the problem is the legal sys-



We may not have free will, but
we do have “free won’t”—veto
power over criminal intent.

Responsibility exists in the rules of a society, not in the neuronal structures of the brain.



tem's view of human behavior. It assumes Harry is a "practical reasoner," a person who acts because he has freely chosen to act. This simple but powerful assumption drives the entire legal system. Even though we might all conceive of reasons to contravene the law, we can decide not to act on such thoughts because we have free will. If a defense lawyer can provide evidence that a defendant had a "defect in reasoning" that led to his inability to stop from committing the crime, then Harry can be deemed exculpable. The legal authorities want a brain image, a neurotransmitter assay or something to show beyond a reasonable doubt that Harry was not thinking clearly, indeed *could not* think clearly, and therefore could not stop his behavior.

The view of human behavior offered by neuroscience is at odds with this perspective. In some ways, it is a tougher view, in other ways more lenient. Fundamentally, however, it is different. Neuroscience is the business of describing the mechanistic actions of the nervous system. The brain is an evolved system, a decision-making device that interacts with its environment in a way that allows it to learn rules to govern how it responds. It is a rule-based device that, fortunately, works automatically.

Critics might raise the objection: "Aren't you saying that people are basically robots? That the brain is a clock, and you can't hold people responsible for criminal behavior any more than you can blame a clock for not working?" That is not the case. The comparison is inappropriate because the notion of responsibility has not emerged. It has not been denied; it is simply absent from the neuroscientific description of human behavior, as a direct result of treating the brain as an automatic machine. But just because responsibility cannot be assigned to clocks does not mean it cannot be ascribed to people. In this sense, human beings are special and different from robots.

This is a fundamental point. Neuroscience will never find the brain correlate of responsibility, because that is something we ascribe to people, not to brains. It is a moral value we demand of our fellow rule-following human beings. Brain scientists might be able to tell us what someone's mental state or brain condition is but cannot tell us when someone has too little control to be held responsible. The issue of responsibility is a social choice. According to neuroscience, no one person is more or less responsible than any other person for actions carried out. Responsibility is a social construct and exists in the rules of the society. It does not exist in the neuronal structures of the brain.

For now, that is all we can say. It would be rash to conclude on any other note than one of modesty about our current understanding of the brain and mind. Much more work is needed to clarify the complex issues raised by neuroscience and the law.

Still, we would like to offer the following axiom: brains are automatic, rule-governed, determined devices, whereas people are personally responsible agents free to make their own decisions. Just as traffic is what happens when physically determined cars interact, responsibility is what happens when people interact. Brains are determined; people are free.

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(Further Reading)

- ▣ **Do We Have Free Will?** Benjamin Libet in *Journal of Consciousness Studies*, Vol. 6, Nos. 8–9, pages 47–57; 1999.
- ▣ **A Neural Basis for Sociopathy.** Antonio R. Damasio in *Archives of General Psychiatry*, Vol. 57, pages 128–129; 2000.
- ▣ **The Divergence of Neuroscience and Law.** J. R. Waldbauer and Michael S. Gazzaniga in *Jurimetrics*, Vol. 41, No. 3, Symposium Issue; 2001.



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BY SCOTT O. LILIENFELD, JAMES M. WOOD AND HOWARD N. GARB

What's Wrong with This

PICTURE BY INK BLOTS?

Photographs by Jelle Wagenaar

Psychologists often use the famous Rorschach inkblot test and related tools to assess personality and mental illness. But research says the instruments are frequently ineffective for those purposes

What if you were asked to describe images

you saw in an inkblot or to invent a story for an ambiguous illustration—say, of a middle-aged man looking away from a woman who was grabbing his arm? To comply, you would draw on your own emotions, experiences, memories and imagination. You would, in short, project yourself into the images. Once you did that, many practicing psychologists would assert, trained evaluators could mine your musings to reach conclusions about your personality traits, unconscious needs and overall mental health.

But how correct would they be? The answer is important because psychologists frequently apply such “projective” instruments (which present people with ambiguous images, words or objects) as components of mental assessments, and the outcomes can profoundly affect the lives of the respondents. The tools often serve, for instance, as aids in diagnosing mental illness, in predicting whether convicts are likely to become violent after being paroled, in evaluating the mental stability of parents engaged in custody battles, and in discerning whether children have been sexually molested.

To gauge their relevance, we have reviewed a large body of research into how well projective methods work, concentrating on three of the most extensively used and best-studied instruments. Overall our findings are unsettling.

Butterflies or Bison?

The famous Rorschach inkblot test—which asks people to describe what they see in a series of 10 inkblots—is by far the most popular of the projective methods, given to hundreds of thousands, or perhaps millions, of people every year.

The research discussed below refers to the modern, rehabilitated version, not to the original construction, introduced in the 1920s by Swiss psychiatrist Hermann Rorschach.

The initial tool came under severe attack in the 1950s and 1960s, in part because it lacked standardized procedures and a set of norms (averaged results from the general population). Standardization is important because seemingly trivial differences in the way an instrument is administered can affect a person’s responses to it. Norms provide a reference point for determining when someone’s responses fall outside an acceptable range.

In the 1970s John E. Exner, Jr., then at Long Island University, ostensibly corrected the problems in the early Rorschach test by introducing what he called the Comprehensive System. This set of instructions established detailed rules for delivering and scoring the inkblot exam and for interpreting the responses, and it provided norms for children and adults.

In spite of the Comprehensive System’s current popularity, it generally falls short on two crucial criteria that were also problematic for the

Rorschach Test: Wasted Ink?

"It looks like two dinosaurs with huge heads and tiny bodies. They're moving away from each other but looking back. The black blob in the middle reminds me of a spaceship."

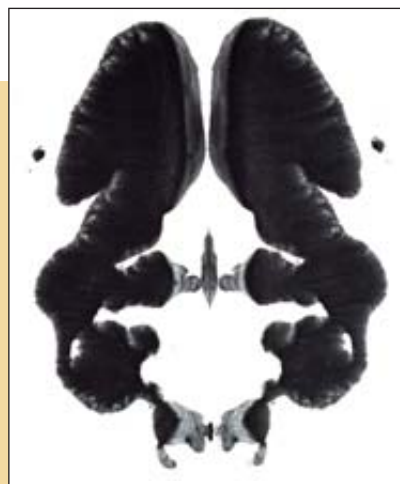
Once deemed an "x-ray of the mind," the Rorschach inkblot test remains the most famous—and infamous—projective psychological technique. An examiner hands 10 symmetrical inkblots one at a time in a set order to a viewer, who says what each blot resembles. Five blots contain color; five are black and gray. Respondents can rotate the images. The one shown here is an inverted version of an Andy Warhol rendering; the Rorschach publisher prefers that the blots not be published.

Responses to the inkblots purport-

edly reveal aspects of a person's personality and mental health. Advocates believe, for instance, that references to moving animals—such as the dinosaurs mentioned above—often indicate impulsiveness; allusions to a blot's "blackness"—as in the spaceship—often indicate depression.

Swiss psychiatrist Hermann Rorschach probably got the idea of showing inkblots from a European parlor game. The test debuted in 1921 and reached high status by 1945. But a critical backlash began taking shape in the 1950s, as researchers found that psychologists often interpreted the same responses differently and that particular responses did not correlate well with specific mental illnesses or personality traits.

Today the Comprehensive System,



meant to remedy those weaknesses, is widely used to score and interpret Rorschach responses. But it has been criticized on similar grounds. Moreover, several recent findings indicate that the Comprehensive System incorrectly labels many normal respondents as pathological.

original Rorschach: scoring reliability and validity. A tool possessing scoring reliability yields similar results regardless of who grades and tabulates the responses. A valid technique measures what it aims to measure: its results are consistent with those produced by other trustworthy instruments or are able to predict behavior, or both.

To understand the Rorschach's scoring reliability defects, it helps to know something about how reactions to the inkblots are interpreted. First, a psychologist rates the collected reactions on more than 100 characteristics, or variables. The evaluator, for instance, records whether the person looked at whole blots or just parts, notes whether the detected images were unusual or typical of most test takers, and indicates which aspects of the inky swirls (such as form or color) most de-

termined what the respondent reported seeing.

Then the examiner compiles the findings into a psychological profile of the individual. As part of that interpretative process, psychologists might conclude that focusing on minor details (such as stray splotches) in the blots, instead of on whole images, signals obsessiveness in a patient and that seeing things in the white spaces within the larger blots, instead of in the inked areas, reveals a negative, contrary streak.

For the scoring of any variable to be considered highly reliable, two different assessors should be very likely to produce similar ratings when examining any given person's responses. Recent investigations demonstrate, however, that many of the Rorschach scores weighted heavily by clinicians display unsatisfactory agreement. As a consequence, clinicians may often arrive at quite different interpretations of people's responses.

Equally troubling, analyses of the Rorschach's validity indicate that it is poorly equipped to identify most psychiatric conditions—with the notable exceptions of schizophrenia and other disturbances marked by disordered thoughts, such as bipolar disorder (manic depression). Despite claims by some Rorschach proponents, the method does not consistently detect depression, anxiety disorders or antisocial personality (a condition characterized by dishonesty, callousness and lack of guilt).

(The Authors)

SCOTT O. LILIENTELD, JAMES M. WOOD and HOWARD N. GARB all conduct research on psychological assessment tools. They recently collaborated on an extensive review of research into projective instruments that was published by the American Psychological Society [see "Further Reading," on page 57]. Lilienfeld and Wood are associate professors in the departments of psychology at Emory University and the University of Texas at El Paso, respectively. Garb is a clinical psychologist at Wilford Hall Medical Center at Lackland Air Force Base in San Antonio, Tex., and author of the book *Studying the Clinician: Judgment Research and Psychological Assessment*.

Moreover, although psychologists frequently administer the Rorschach to assess propensities toward violence, impulsiveness and criminal behavior, most research suggests it is not valid for these purposes either. Similarly, no compelling evidence supports its use for helping to detect sexual abuse in children.

Other problems have surfaced as well. Some evidence indicates that the Rorschach norms meant to distinguish mental health from mental illness are unrepresentative of the U.S. population and mistakenly make many adults and children seem maladjusted. For instance, in a 1999 study of 123 adult volunteers at a California blood bank, one in six had scores supposedly indicative of schizophrenia.

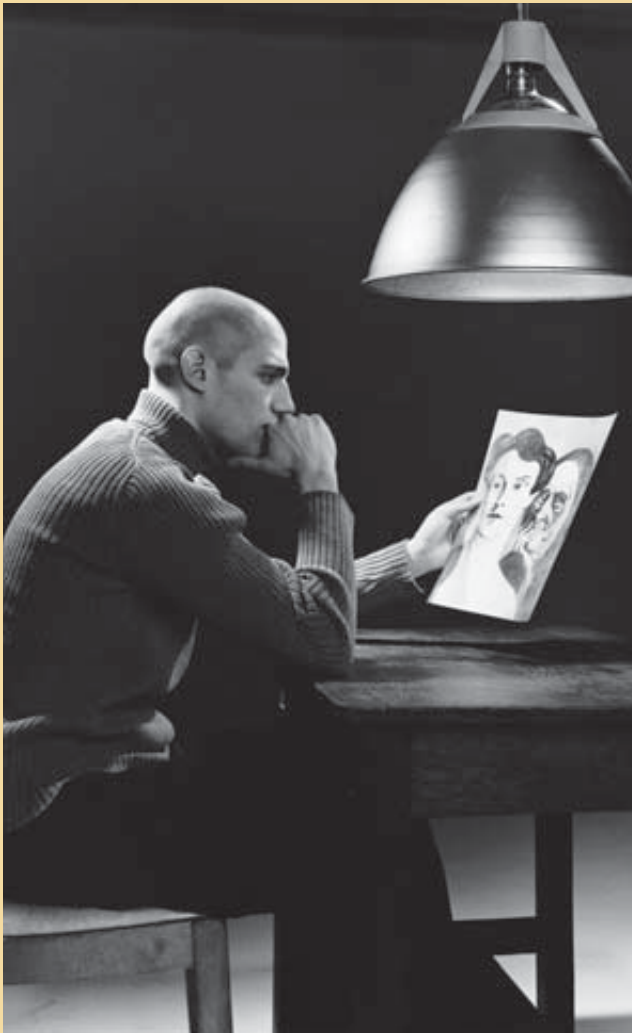
The inkblot results may be even more mis-

leading for minorities. Several investigations have shown that scores for African-Americans, Native Americans, Native Alaskans, Hispanics, and Central and South Americans differ markedly from the norms. Together the collected research raises serious doubts about the use of the Rorschach inkblots in the psychotherapy office and in the courtroom.

Doubts about TAT

Another projective tool—the Thematic Apperception Test (TAT)—may be as problematic as the Rorschach. This method asks respondents to formulate a story based on ambiguous scenes in drawings on cards. Among the 31 cards available to psychologists are ones depicting a boy contemplating a violin, a distraught woman clutching an

Thematic Apperception Test: Picture Perfect



The Thematic Apperception Test (TAT), created by Harvard University psychiatrist Henry A. Murray and his student Christiana Morgan in the 1930s, is among the most commonly used projective measures. Examiners present individuals with a subset (typically five to 12) of 31 cards displaying pictures of ambiguous situations, mostly featuring people. Respondents then construct a story about each picture, describing the events that are occurring, what led up to them, what the characters are thinking and feeling, and what will happen later. Many variations of the TAT are in use, such as the Children's Apperception Test, featuring animals interacting in ambiguous situations, and the Blacky Test, featuring the adventures of a black dog and its family.

Psychologists have several ways of interpreting responses to the TAT. One promising approach—developed by Emory University psychologist Drew Westen—relies on a specific scoring system to assess people’s perceptions of others (“object relations”). According to that approach, if someone wove a story about an older woman plotting against a younger person in response to the image visible in the photograph at the left, the story would imply that the respondent tends to see malevolence in others—but only if similar themes turned up in stories told about other cards.

Surveys show, however, that most practitioners do not use systematic scoring systems to interpret TAT stories, relying instead on their intuitions. Unfortunately, research indicates that such “impressionistic” interpretations of the TAT are of doubtful validity and may make the TAT a projective exercise for both examiner and examinee.

Other Projective Tools: What's the Score?

P psychologists have dozens of projective methods to choose from beyond the Rorschach test, the TAT and figure drawings. As the sampling below indicates, some stand up well to the scrutiny of research, but many do not.

Hand test. Subjects say what hands pictured in various positions might be doing. This method is used to assess aggression, anxiety and other personality traits, but it has not been well studied.

Handwriting analysis (graphology). Interpreters rely on specific “signs” in a person’s handwriting to assess personality characteristics. Though useless, the method is still used to screen prospective employees.

Lüscher color test. People rank colored cards in order of preference to reveal personality traits. Most studies find the technique to lack merit.

Play with anatomically correct dolls. Research finds that

sexually abused children often play with the dolls’ genitalia; however, that behavior is not diagnostic, because many nonabused children do the same thing.

Rosenzweig picture frustration study. After one cartoon character makes a provocative remark to another, a viewer decides how the second character should respond. This instrument, featured in the movie *A Clockwork Orange*, successfully predicts aggression in children.

Sentence completion test. Test takers finish a sentence, such as, “If only I could . . .” Most versions are poorly studied, but one developed by Jane Loevinger of Washington University is valid for measuring aspects of ego development, such as morality and empathy.

Szondi test. From photographs of patients with various psychiatric disorders, viewers select the ones they like most and least. This technique assumes that the selections reveal something about the choosers’ needs, but research has discredited it.

open door, and a woman who is grabbing the arm of a man who is looking away. One card, the epitome of ambiguity, is totally blank.

The TAT has been called “a clinician’s delight and a statistician’s nightmare,” in part because its administration is usually not standardized: different clinicians present different numbers and selections of cards to respondents. Also, most clinicians interpret people’s stories intuitively instead of following a well-tested scoring procedure. Indeed, a recent survey of nearly 100 North American psychologists practicing in juvenile and family courts discovered that only 3 percent relied on a standardized TAT scoring system. Unfortunately, some evidence suggests that clinicians who interpret the TAT in an intuitive way are likely to overdiagnose psychological disturbance.

Many standardized scoring systems are available for the TAT, but some of the more popular ones display weak “test-retest” reliability: they tend to yield inconsistent scores from one picture-viewing session to the next. Their validity is frequently questionable as well; studies that find positive results are often contradicted by other investigations. For example, several scoring systems have proved unable to differentiate normal individuals from those who are psychotic or depressed.

A few standardized scoring systems for the TAT do appear to do a good job of discerning certain aspects of personality—notably the need to achieve and a person’s perceptions of others (a property called “object relations”). But many times individuals who display a high need to achieve do not score well on measures of actual achievement, so the ability of that variable to predict a person’s behavior may be limited. These scoring systems currently lack adequate norms and so are not yet ready for application outside of research settings, but they merit further investigation for possible use in therapy.

Faults in the Figures

In contrast to the Rorschach and the TAT, which elicit reactions to existing images, a third projective approach asks the people being evaluated to draw the pictures. A number of these instruments, such as the frequently applied Draw-a-Person Test, have examinees depict a human being; others have them draw houses or trees as well. Clinicians commonly interpret the sketches by relating specific “signs”—such as features of the body or clothing—to facets of personality or to particular psychological disorders. They might associate large eyes with paranoia, long neckties with sexual aggression, missing facial features with depression, and so on.

Human Figure Drawings: Misleading Signs

P sychologists have many projective drawing instruments at their disposal, but the Draw-a-Person Test is among the most popular—especially for assessing children and adolescents. A clinician asks the child to draw someone of the same sex and then someone of the opposite sex in any way that he or she wishes. (A variation involves asking the child to draw a person, house and tree.) Those who employ the test believe that the drawings reveal meaningful information about the child's personality or mental health.

In a sketch of a man, for example, small feet would supposedly indicate insecurity or instability—a small head, inadequacy. Large hands or teeth would be considered signs of aggression; short arms, a sign of shyness. And feminine features—such as long eyelashes or darkly col-

ored lips—would allegedly suggest sex-role confusion.

Yet research consistently shows that such “signs” bear virtually no relation to personality or mental illness. Scientists have denounced these sign interpretations

as “phrenology for the 20th century,” recalling the 19th-century pseudoscience of inferring people's personalities from the pattern of bumps on their skulls.

Still, the sign approach remains widely used. Some psychologists even claim that certain key signs are suggestive of sexual abuse. For instance, in the child's drawing at the right, alleged signs of abuse include a person older than the child, a partially unclothed body, a hand near the genitals, a hand hidden in a pocket, a large nose and a mustache. In reality, the connection between these signs and sexual abuse remains dubious at best.



As is true of the other methods, the research on drawing instruments gives reason for serious concern. In some studies, raters agree well on scoring outcomes, yet in others the agreement is poor. What is worse, no strong evidence supports the validity of the sign approach to interpretation; in other words, clinicians apparently have no grounds for linking specific signs to particular personality traits or psychiatric diagnoses. Nor is there consistent evidence that signs purportedly linked to child sexual abuse (such as tongues or genitalia) actually reveal a history of molestation.

The only positive result found repeatedly is that, as a group, people who draw human figures poorly have somewhat elevated rates of psychological disorders. On the other hand, studies show that clinicians are likely to attribute mental illness to many normal individuals who simply lack artistic ability.

Certain proponents argue that sign approaches can be valid in the hands of seasoned experts. Yet one group of researchers reported that experts who administered the Draw-a-Person Test were less accurate than graduate stu-

dents at distinguishing psychological normality from abnormality.

A few global scoring systems, which are not based on the interpretation of signs, might be useful. Instead of assuming a one-to-one correspondence between a particular feature of a drawing and a personality trait, psychologists who apply such methods combine many aspects of the pictures to come up with a general impression of a person's adjustment. In a study of 52 children, a global scoring approach helped to distinguish normal individuals from those with mood or anxiety disorders. In another report, global interpretation correctly differentiated 54 normal children and adolescents from those who were overly aggressive or who were extremely disobedient. The global approach may work better than the sign approach because the act of aggregating information can cancel out “noise” from variables that provide misleading or incomplete information.

Our literature review, then, indicates that, as usually administered, the Rorschach, TAT and human figure drawings are useful only in very limited circumstances. The same is true for

many other projective techniques [see box on page 55].

We have also found that even when the methods assess the psychological traits they claim to measure, they tend to lack what psychologists call “incremental validity”: they rarely add much to information that can be obtained in other, more practical ways, such as by conducting interviews or administering objective personality tests. (Objective tests seek answers to relatively clear-cut questions, such as “I frequently have thoughts of hurting myself—true or false?”) The lack of added insight provided by projective tools makes their costs in money and time hard to justify.

What to Do?

Some mental health professionals disagree with our conclusions. They argue that projective tools have a long history of constructive use and, when administered and interpreted properly, can cut through the veneer of respondents’ self-reports to provide a picture of the deepest recesses of the mind. Our critics have also asserted that we have emphasized negative findings to the exclusion of positive ones.

Yet we remain confident in our conclusions. In fact, as negative as our overall findings are, they may paint an overly rosy picture of projective techniques because of the so-called file drawer effect. As is well known, scientific journals are more likely to publish reports demonstrating that some procedure works than reports finding failure. Consequently, researchers often quietly file away their negative data, which may never again see the light of day.

We find it troubling that psychologists commonly administer projective instruments in situations for which their value has not been well established by multiple studies; too many people can suffer if erroneous diagnostic judgments influence therapy plans, custody rulings or criminal court decisions. Based on our findings, we strongly urge psychologists to curtail their use of most projective techniques and, when they do select such instruments, to limit themselves to scoring and interpreting the small number of variables that have been proved trustworthy.

Our results also offer a broader lesson for practicing clinicians, psychology students and the public at large: even seasoned professionals can be fooled by their intuitions and their faith in tools that lack strong evidence of effectiveness. When a substantial body of research demonstrates that old intuitions are wrong, it is time to adopt new ways of thinking.

Popularity Poll: How Often the Tools Are Used

In 1995 a survey asked 412 randomly selected clinical psychologists in the American Psychological Association how often they used various projective and nonprojective assessment tools, including those listed below. Projective instruments present people with ambiguous pictures, words or objects; the other measures are less open-ended. The number of clinicians who use projective methods might have declined slightly since 1995, but these techniques remain widely used.

PROJECTIVE TECHNIQUES	USE ALWAYS OR FREQUENTLY	USE AT LEAST OCCASIONALLY
Rorschach	43%	82%
Human figure drawings	39%	80%
Thematic Apperception Test (TAT)	34%	82%
Sentence completion tests	34%	84%
CAT (Children’s version of the TAT)	6%	42%
NONPROJECTIVE TECHNIQUES*	USE ALWAYS OR FREQUENTLY	USE AT LEAST OCCASIONALLY
Wechsler Adult Intelligence Scale (WAIS)	59%	93%
Minnesota Multiphasic Personality Inventory-2 (MMPI-2)	58%	85%
Wechsler Intelligence Scale for Children (WISC)	42%	69%
Beck Depression Inventory	21%	71%

*Those listed are the most commonly used nonprojective tests for assessing adult IQ (WAIS), personality (MMPI-2), childhood IQ (WISC) and depression (Beck Depression Inventory).

SOURCE: “Contemporary Practice of Psychological Assessment by Clinical Psychologists,” by C. E. Watkins et al. in *Professional Psychology: Research and Practice*, Vol. 26, No. 1, pages 54–60; 1995. For more insight, see also “What Tests Are Acceptable for Use in Forensic Evaluations? A Survey of Experts,” by S. J. Lally in *Professional Psychology: Research and Practice*, Vol. 34, No. 5, pages 491–498; 2003.

(Further Reading)

- ▣ **The Scientific Status of Projective Techniques.** Scott O. Lilienfeld, James M. Wood and Howard N. Garb in *Psychological Science in the Public Interest*, Vol. 1, No. 2, pages 27–66; November 2000. Available at www.psychologicalscience.org/journals/pspi/pdf/pspi1_2.pdf
- ▣ **The Rorschach: A Comprehensive System, Vol. 1: Basic Foundations and Principles of Interpretation.** Fourth edition. John E. Exner. John Wiley & Sons, 2002.
- ▣ **A Critique of Lilienfeld et al.’s (2000) “The Scientific Status of Projective Techniques.”** Stephen Hibbard in *Journal of Personality Assessment*, Vol. 80, No. 3, pages 260–271; 2003.
- ▣ **Science and Pseudoscience in Clinical Psychology.** Edited by Scott O. Lilienfeld, Steven Jay Lynn and Jeffrey M. Lohr. Guilford, 2003.
- ▣ **What’s Wrong with the Rorschach? Science Confronts the Controversial Inkblot Test.** James M. Wood et al. Jossey-Bass, 2003.
- ▣ **The Cult of Personality: How Personality Tests Are Leading Us to Miseducate Our Children, Mismanage Our Companies, and Misunderstand Ourselves.** Annie Murphy Paul. Free Press, 2004.

Alien Friends

For people with Capgras syndrome, loved ones have been taken over by body doubles. Their experience teaches us that feelings are integral to perception

BY THOMAS GRÜTER AND ULRICH KRAFT

Nothing puts the horror into a horror film like an idyllic setting. That is how the 1956 science-fiction classic *Invasion of the Body Snatchers* begins. The inhabitants of the bucolic hamlet of Santa Mira, Calif., delight in their neighborly friendships and rarely have more than the most mundane concerns. But when town doctor Miles Bennell returns home after a short trip, he learns that one of his patients thinks her uncle is not really himself. The woman feels almost as if something evil is lurking behind his familiar face. Bennell is not too concerned. But then more and more patients become suspicious that a body double has replaced a spouse, relative or neighbor. Many of the doubles seem threatening, too. Bennell's sense of strangeness soon turns to awful certainty: alien invaders have chosen Santa Mira as the staging area for world domination. Under cover of night, they are taking over the bodies of their sleeping victims.

The insidious terror depicted in *Invasion of the Body Snatchers* exploits a primal human fear of total isolation: everyone we know becomes alien, leaving us utterly alone amid uncomprehending strangers who care nothing about our life or death. Moviegoers can escape this creepy world of doubles, but for people with Capgras syndrome, it is reality. Day in and day out, they firmly believe that certain people they know intimately have been replaced by robots, extraterrestrials or human doubles.

Capgras syndrome is relatively rare, but the symptoms clearly demonstrate that our internal image of the external world is not a one-to-one mapping of the sights and sounds our eyes and ears take in. The brain



JULIA FULLERTON-BATTEN Stone/Getty Images



processes and filters the flood of information at a variety of levels that we are unaware of. Only the end result adds up to consciousness as we know it, and for Capgras patients this reality looks a lot like the body snatchers film. Their eerie experiences show that perception consists not just of sensory inputs but also of feelings. The lesson of Capgras syndrome is that even our “normal” reality may be little more than a delusion.



Doctor Miles Bennell (far right) and friends fend off alien impostors in the 1956 movie *Invasion of the Body Snatchers*.

Eighty Husbands

The bizarre misperception of body doubles is named after French psychiatrist Jean Marie Joseph Capgras, who in 1923 with colleague Jean Reboul-Lachaux described the case of a Madame M. The woman insisted that identical-looking persons had taken the place of her family. Nothing could dislodge her belief. Over time her delusion expanded to neighbors, friends and acquaintances. But Madame M. never even got to know these impostors, because, she believed, they regularly moved out to make room for the next double. In the end, she claimed to have had more than 80 husbands.

The proper name for such a condition is Capgras delusion syndrome, with “delusion” implying an incorrect assessment of a correct perception. In contrast, a person who suffers hallucinations is experiencing perceptions that have no basis in reality. A delusion is a false belief, based on incorrect inferences about external reality, that is sustained despite what almost everyone else believes and regardless of obvious proof to the contrary.

Delusions take many forms. A schizophrenic woman may insist that a wilted piece of lettuce in a salad is proof that someone is out to poison her; an open window is a sure sign that her conversations are being monitored. Nothing can persuade

her about the groundlessness of her theories. If a psychiatrist pushes countering views too hard, she will add him to her list of suspected enemies.

Luckily, many schizophrenic delusions turn out to be transient, but while they last the patient is unable to recognize them for what they are. These cases differ, however, from so-called monothematic delusions, such as Capgras syndrome, which focus on a single topic and are often considerably longer lived [see box on page 62]. Patients may first develop their delusions as a result of biological changes in the brain—perhaps caused by dementia, stroke, aneurysm or brain injury. Indeed, a metastudy published in November 2004 by Dominique Bourget and Laurie Whitehurst of the University of Ottawa indicates many patients have lesions or abnormalities in their right hemisphere. But often the false perceptions arise from psychiatric diseases such as schizophrenia and Alzheimer’s disease.

One patient, David, whose delusions began after an accident, was studied by neuroscientist Vilayanur S. Ramachandran, director of the Center for Brain and Cognition at the University of California at San Diego, and William Hirstein, a neuroscientist and philosopher now at Elmhurst College. In Ramachandran’s book *Phantoms in the Brain* (Perennial, 1999), the man first claims that his mother and father have been replaced by a double. Not even the unchanged behavior of the rest of his family members can cast any doubt in his mind. In the book, Ramachandran points out that traditional psychology would attribute such delusions to Freud’s Oedipus complex, according to which boys are sexually attracted to their mothers. Brain injuries abruptly reawaken these long-dormant wishes and plunge the victim into a state of severe conflict: “If she’s my mother, how can I possibly feel sexual desire for her?” The way out: “She must be a different woman who only looks like my mother.”

As Ramachandran subsequently notes, Freud’s theory has long been discredited because of its obvious weaknesses. First, as the case with Madam M. shows, Capgras syndrome affects women as well as men. Second, patients do not by any means exclusively suspect their mothers.

Missing Emotions

When Capgras syndrome develops, it is often soon after a severe head injury, as was the case with David. This correlation suggests that the disease arises from neurological malfunction. In the early 1990s psychologists Hadyn D. Ellis of Cardiff University and Andrew W. Young, now at

DEFD

Many Capgras sufferers feel threatened by the supposed body doubles and, unfortunately, react accordingly.

the University of York, both in the U.K., suggested that Capgras syndrome might be caused by an impairment of object recognition and, in particular, facial recognition.

When we look at a face, neural impulses normally flow from the retina to the visual centers in the right temporal lobe, where perception emerges into conscious awareness. At the same time, the brain arouses our memories of faces, compares them with the present one, and establishes whether or not we have seen it before. All this appears to proceed normally in Capgras patients. They recognize a face correctly and can name the person to whom it belongs. But then they deny that the face is authentic. This means that in addition to the conscious pathway, there must be a second mechanism by which we ascribe a suitable identity to a particular face.

Seeing is more than a physical perceptual process. For example, a person does not admire a painting just for its deft brushstrokes or a certain combination of colors but for the emotions the painting elicits. Feelings are an integral part of the visual process. And indeed, neural pathways run from the vision centers to the amygdala, the seat of our emotional system. The face of a familiar person is thus coupled with the emotions that are linked to her identity, which are retrieved whenever we think of or see her.

The ability to make such associations appears to be impaired in Capgras syndrome. David, for example, looks at his mother and knows that the face he is perceiving belongs to her, yet it does not make him feel warmth or love. As Ellis hypothesizes, this disconnect creates a severe contradiction in David's experiential world. The challenge to David's brain might be summarized as follows: "How can this woman be my mother if her face leaves me completely cold? Something doesn't add up. Solution: It must be someone else, someone trying to pass herself off as my mother. A double!" As bizarre as this conclusion may seem, it makes perfect sense from the perspective of the brain, which will concoct whatever story is necessary to prevent the person's inner belief system from crumbling. Some experts think that Capgras delusion may be a protective mechanism employed by a brain that might otherwise be stymied by internal contradictions. Because distortion of the image of the external world largely occurs before the images reach con-

scious awareness, patients are unshakable in their delusion. They cannot be talked out of it by logic or reason, because they do not know that their brain has engaged in any manipulation.

Fake Voices

Intrigued by the possibility that emotion influences perception, in 2001 Ellis and his Cardiff colleague Michael B. Lewis turned to a device similar to a lie detector, which measures certain physiological changes. Feelings such as fear or happiness affect the autonomic nervous system, which controls the blood vessels in the skin as well as the sweat glands. Fear and happiness increase sweat production, which changes the skin's electrical resistance—a variable that the device measures. Although this link is a crude indicator, it nonetheless reliably reflects the strength of an emotional reaction.

When researchers show healthy test subjects photographs of people they know personally, their skin resistance changes. But when Ellis and Lewis had conducted this experiment the previous year with Capgras patients, skin conductance remained unchanged. Even though the subjects recognized the faces of family members, the experience triggered no emotional response. This result helped to confirm that in Capgras patients, the unconscious association between a known person and the feeling attributed to that person is impaired [see illustration on page 63]. (This unusual circumstance is the converse of "face blindness," or prosopagnosia: a malfunction in the ability to recognize faces. An affected person will deny ever having seen the face of a close friend, even though they do exhibit the appropriate emotional reaction.)

Interestingly, there have been several reports of blind people who have Capgras syndrome. The disconnect is auditory. Analogous to the visual pathways, neural pathways also connect the auditory cortex to the amygdala and other emotion centers. The auditory pathways mediate the



Hadyn D. Ellis of Cardiff University says Capgras syndrome may be caused by faulty facial recognition.

(The Authors)

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Mistaken Identity

Capgras syndrome belongs to a class of exotic conditions known as monothematic delusions, in which patients are preoccupied by a single topic over a long period. Frégoli syndrome, reduplicative disorder and Cotard syndrome belong to this class as well.

Frégoli syndrome. This type of delusion, described in 1927, was named after Italian actor Leopoldo Frégoli, still considered one of the greatest quick-change artists of all time. In his one-man performances, he portrayed as many as 60 different characters, switching identities at lightning speed.

Similarly, a patient with Frégoli syndrome lives in a mental world full of quick-change artists. He perceives complete strangers as old friends or acquaintances who have cleverly disguised their appearance—but not quite cleverly enough. The patient “knows” that the television newscaster is his brother because he recognizes particular movements or tones of voice, even though there is only the slightest similarity. In extreme cases, those who suffer from the syndrome see the same person in everyone they meet and often feel persecuted by this ever present individual.

Some experts think that Frégoli patients seem to have an overabundance of connections between visual pathways and emotional centers. As a result, complete strangers elicit feelings of familiarity and closeness. The brain “explains” this overidentification by positing a world full of quick-change artists.

Reduplicative disorder. This umbrella term includes de-

lusions arising from the belief that several copies of a phenomenon (not just a person) exist. People with reduplicative paramnesia are convinced that a room, building or even an entire town has several duplicates, each one a perfect reproduction of the original. When the delusion extends to people, patients believe that a friend or acquaintance has one or many doubles that do not replace the original person but exist simultaneously. Because reduplicative disorders are also often accompanied by Capgras syndrome, it is assumed that they are caused by a defect in object perception.

In extremely rare cases, the delusion extends to time. An individual believes that an event occurring in the present took place in precisely the same way once before; the person experiences everything in permanent *déjà vu*.

Cotard syndrome. Cotard patients are deluded not about others but about themselves. They lose all sense of their own physical existence and feel that they have died emotionally. In extreme cases, they believe they are actually dead.

Cotard syndrome may be an extreme form of Capgras delusion. Whereas Capgras patients cannot connect particular

faces with emotions, Cotard patients have no emotional response to any stimulus. Because they feel nothing, they conclude that they do not exist. Even though the condition is almost always associated with severe depression or psychosis, it apparently has neurobiological causes—perhaps damage to the right hemisphere, which plays a crucial role in creating our internal picture of ourselves.

—T.G. and U.K.



Quick-change artist Leopoldo Frégoli—the namesake of Frégoli syndrome—played as many as 60 characters in his one-man performances.

warm feelings elicited, for instance, by a dear friend’s voice. In blind Capgras patients this neuronal connection is thought to be interrupted, and they can suspect that the voice of a loved one is really coming from an impostor.

This insight can be handy for family members who must deal with loved ones with Capgras. David’s auditory pathways were intact, for example, and his parents made full use of them. Whenever he accused his mother of being a deceitful fake, she would simply walk into another room and call him from a telephone there. Whenever David talked to his mother on the phone, he never doubted her identity.

Old Friends in a New Light

Other than their mistaken theories about doubles and aliens, people with Capgras syndrome are quite normal. The condition harms only a small piece of the perceptual apparatus, albeit a crucial one. Yet because this delusion can also affect blind persons, it seems the impairment impinges on more than facial recognition. It strikes at the basic ability to identify others.

Although Ellis’s neurobiological model provides an elegant explanation, it does leave several questions open. For example, a Capgras delusion is almost always very specific; it doubts the identity of only certain people, even when the patient

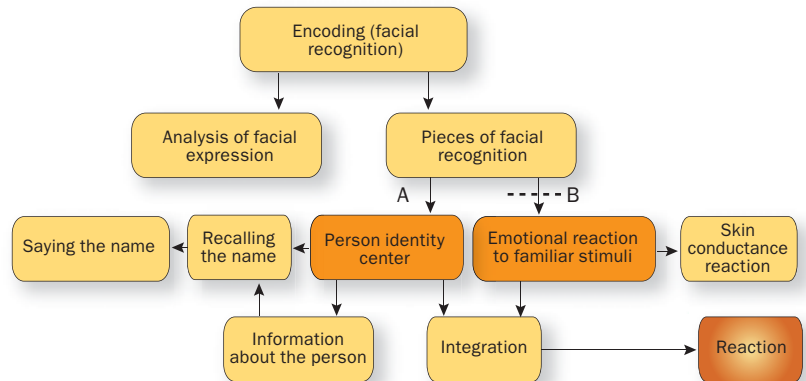
has no problem identifying others with whom he is equally close. This is problematic for researchers: if the cause is a damaged link between the site of conscious perception in the cortex and the emotion centers, how can someone claim that his mother is a double but not his father? According to neurologist and psychiatrist Todd E. Feinberg of Albert Einstein College of Medicine, the problem is much deeper: before the onset of Capgras symptoms, patients must have had a loaded or ambivalent emotional relationship to the persons they later fail to recognize. This view is supported by Ellis and Lewis's observation that many patients are extremely suspicious of the supposed doubles and even of those people they consider to be "real." Studies seem to suggest that the condition tends to develop against a backdrop of clinical paranoia. Then again, it is easy to understand how someone who suddenly perceives family members as strangers would conclude that he is the victim of a huge conspiracy.

As with schizophrenia, with which Capgras is most frequently associated, the delusion arises in a patient who is emotionally "flattened." In contrast to injuries or stroke, schizophrenia involves no actual damage to brain tissue. Yet schizophrenia patients often barely feel positive emotions. If the diffuse aura of threat is added to this condition—which many schizophrenics feel already—the seeds of a delusion like Capgras syndrome have been sown. It is interesting to note that the Capgras delusion frequently disappears toward the end of an acute schizophrenic phase.

Another unanswered question is why people with Capgras delusion defend their theory of doubles against all reasoned arguments. Although it seems that the brain is defending its inner belief system, patients are well aware that relatives and doctors reject their claims. The patients almost never ask the obvious questions: "If an alien has replaced my wife, where is my real wife?" "Shouldn't I go to the police?" "Shouldn't I warn the world about this extraterrestrial invasion?"

Unfortunately, an unshakably distorted picture of the external world can sometimes lead to terrible consequences. Many Capgras sufferers consider their doubles to be evil, feel threatened by the impostors and react accordingly. Arturo Silva, a psychiatrist then at the Veterans Affairs Medical Center in Palo Alto, Calif., compiled 80 cases in which patients attacked a presumed double verbally or physically. Two of the attacks ended in death. Other research shows that most victims are family members.

It is unclear what determines the level of vio-



lence, but it should be kept in mind that Capgras syndrome is often a symptom of a more fundamental disease, such as paranoid schizophrenia. A paranoid schizophrenic sees himself surrounded by a hostile world that forever encroaches on him and attempts to torture him in every way. In these cases, it may well be the underlying psychiatric disease that is dangerous to others rather than the delusion itself. A 2002 study by Lefteris Lykouras of the Athens University Medical School in Greece, as well as research by others, shows certain antipsychotic drugs, such as olanzapine, sulpiride and trifluoperazine, can mitigate some violent tendencies in certain patients.

As bizarre as it may seem, Capgras syndrome is merely an extreme variation on how we all view our everyday experiences. What we perceive is intimately connected with our feelings. Assume for a moment that you have just purchased a dazzling new overcoat. Looking at your beat-up old coat in the closet, you cannot imagine why you wore it for so long. Yet it is the same coat you were perfectly happy to wear just yesterday. What has changed? Your emotional relationship to that coat.

And when an old friend disappoints us, we may shake our heads and say that he is not himself. But is it not more likely that our injured feelings have suddenly placed him in a different light?

Face processing runs along a conscious pathway (A) and an unconscious pathway (B) that is interrupted in Capgras syndrome, according to Hadyn Ellis's model.

(Further Reading)

- ◆ **Capgras Syndrome: A Novel Probe for Understanding the Neural Representation of the Identity and Familiarity of Persons.** William Hirstein and Vilayanur S. Ramachandran in *Proceedings of the Royal Society of London B*, Vol. 264, pages 437–444; 1997.
- ◆ **Capgras Delusion: A Window on Face Recognition.** Hadyn D. Ellis and Michael B. Lewis in *Trends in Cognitive Sciences*, Vol. 5, No. 44, pages 149–156; April 2001.
- ◆ **Capgras Syndrome: A Review of the Neurophysiological Correlates and Presenting Clinical Features in Cases Involving Physical Violence.** Dominique Bourget and Laurie Whitehurst in *Canadian Journal of Psychiatry*, Vol. 49, pages 719–725; November 2004.
- ◆ A useful set of online references can be found at <http://groups.msn.com/TheAutismHomePage/capgrasssyndrome.msnw>

THE WILL TO WIN

More and more athletes are engaging in mental workouts to give them that extra edge

BY STEVE J. AYAN

The Olympic stadium was silent. The spectators held their collective breath. The 100-meter finalists, crouched against their starting blocks, raised their backs as the starter raised his pistol and announced, “Set...!” Each powerful sprinter, poised to explode when the gun went off, was keenly aware of what hung in the balance. They had trained to exhaustion every day for years to prepare their bodies for this one race.

But had they disciplined their minds? The runner who would break the tape would need more than strong muscles, heart and lungs. He would need concentration, control, confidence—and an unerring eye on the finish line. At this tense

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(More and more amateurs are resorting to mental gymnastics to help them **push their own limits.**)

Torture de France: For endurance athletes like Lance Armstrong, confidence comes from knowing how to push past the pain barrier.

moment, one mistimed twitch could cause a false start and cost him the race. But if he eased off in any way, his first steps would lag behind those of his competitors, guaranteeing a loss. “Bang!”

Sports psychology is a booming business. Part of the reason is because elite athletes in many sports are getting closer and closer to one another in terms of physical prowess and talents, leaving thoughts and feelings as the x-factor that brings victory. Many top athletes now find mental train-

ing indispensable—and not just for performing on race or game day but for getting the most out of daily workouts. Many seek help from psychologists, but others go elsewhere: Tour de France champion Lance Armstrong receives regular psychological exercises as well as a daily physical training plan from his personal coach, Chris Carmichael. Formula One auto-racing ace Michael Schumacher has a personal cook, Balbir Singh, who is rumored to double as his spiritual adviser.

Others simply rely on personal rituals to focus their tennis serve or home-run swing.

Often there is little scientific basis for athletes’ mental gymnastics, and the placebo effect cannot be completely ruled out, yet the practices seem to provide a tailwind. Studies show that athletes may profit most by building up psychological strength through three techniques: visualization, confidence and self-talk. The same exercises can work for recreational athletes, too.

See It

Although sports psychologists have supported athletes for more than 30 years, the profession was largely informal until 1983, when the U.S. Olympic Committee established a sports psychology registry. In 1986 the Association for the Advancement of Applied Sport Psychology was founded to promote related science and practices. Since then, the profession has grown briskly: for its 2004 conference, the association received 450 potential presentations.

The practice of visualizing an athletic movement in order to perfect it became popular in the 1970s. Tennis players were among the early adopters. A player standing quietly on the court with his eyes closed would imagine himself hitting the ball,



JOEL SAGET/Getty Images

thinking to himself something like: “My racket is an extension of my arm. My entire body is tingling with excitement, but I am utterly relaxed. I am enjoying every ball that comes flying toward me. I am absolutely sure that with my next stroke I can place the ball in any corner of my opponent’s court. The court is enormously wide.” Psychologist Mihaly Csikszentmihalyi, now at Claremont Graduate University, coined the term “flow” in 1975 to describe this kind of feeling: complete confidence in one’s own actions, blocking out distractions, reveling in the experience.

To put herself into such an ideal performance state, an athlete seeks a healthy balance of strain and relaxation. She must become completely immersed in her own movements. A high jumper must see in her mind exactly each step of her run-up and takeoff and then watch her body glide over the bar. In most visualization training, this focus is achieved by learning to see and subsequently control each concrete component of a movement. In tennis, for example, each stroke consists of “swing, hit, follow-through.” With practice, a tennis player can see the ideal motion with the mind’s eye.

Visualization can benefit training, too, by helping to transform complex motor procedures into automatic movements. The effects on the body of visualization were demonstrated more than a century ago. In the late 1800s English physiologist William Carpenter discovered that imagining movements could elicit reactions in muscles. When we see a soccer player strike a ball toward the goal, our own leg muscles may contract, imperceptibly if not noticeably. This “ideomotor” (or Carpenter) effect, with repeated visualization, can make the real motion easier to perform.

More recently, brain researchers have studied this phenomenon with imaging technologies. Stephen M. Kosslyn, a psychologist at Harvard University, discovered that imagining a movement activates the same motor regions of the cerebral cortex that light up during the actual movement. Most researchers theorize that repeatedly visual-



Visualize: Top shooters such as Allen Iverson repeatedly imagine the ideal arm and hand motions that will help sink free throws.

izing the movement strengthens or adds synaptic connections among relevant neurons. Some basketball players and coaches, for example, claim that repeatedly visualizing the ideal arm and hand motions for a free throw from the foul line improves players’ success rates in actual games: bend the knees, flex the elbow, cock the wrist, then let the ball roll off the fingertips.

And yet some studies indicate that breaking a motion down into parts and concentrating on them in succession can hinder fluid coordination. The alternative is to imagine the outcome—not the motion but its result, such as the ball dropping through the net. Golfer Tiger Woods reports that it is easier for him to sink putts when he imagines the rattle of the ball in the cup.

Believe It

Automating one’s movements frees up the brain to concentrate on other aspects of an athletic challenge. But even more mind control is



Believe: Reaching higher goals builds faith in overcoming tough odds—helping Johnny Damon lead his Boston Red Sox to a comeback World Series victory.

needed. Witness the so-called training champions, who perform outstandingly in workouts but falter or choke when the pressure is on during a real race or game. This perplexing situation is familiar to anyone who has smoothly practiced a joke or magic trick over and over but then stumbles when performing it before an audience. It can be difficult for an athlete facing high stakes, championships and sold-out stadiums to keep calm.

Confidence is the antidote, and it comes from a combination of courage, tolerance and attitude.

exuded to intimidate competitors. Mostly, however, confidence stems from an athlete's faith in himself. That faith is built by regularly setting high but achievable goals in training and in competition. Attaining these goals and then subsequent ones builds motivation and leads to volition—imagining and achieving any goal desired. With full confidence, individuals can overcome enormous challenges.

For endurance athletes, a large part of their confidence comes from knowing how to tolerate pain, how to push their bodies right up to the pain barrier—and then go beyond it. When the 2004 Tour de France races reached the critical point where the leaders would finally break away from the head pack, Jan Ullrich's German teammate Udo Bolts would yell at him: "Torture yourself, you bastard!"

Professional as well as weekend athletes can develop the ability to shut out pain or fear by training hard. They must also expose themselves to the extreme demands of an actual event repeatedly until the ability to tolerate the intensity becomes routine. Furthermore, to rebound from the physical and psychic stress that these experiences impose, muscular and mental relaxation techniques may be in order. One way to reduce anxiety is autogenic training, which teaches athletes to repeat autosuggestive formulas such as "I am completely calm." Physical relief can come

(Dubious figures bill themselves as “**mental coaches**” even though there is no recognized degree.)

The success of Ukrainian pole-vaulter Sergei Bubka, who won six world championships in the 1980s and 1990s, showed just how important courage can be. Bubka did not dominate his event because of extraordinary physical talent. In this physically and technically demanding sport, every vaulter's knees tremble just before he starts his approach to the bar. But not Bubka's. After hoisting his pole, he would run toward the pit like a crazy man, as if he had no fear at all.

Most champion athletes are usually in good psychological shape; if they weren't, they would not have reached such a high level of achievement. Various studies have found that top athletes have a greater ability to concentrate and a stronger will to perform than ordinary mortals. These athletes brim with self-confidence during competitions. Part of this surety is an attitude that is purposely

from practices such as progressive muscle relaxation, which involves alternating contractions and relaxations of individual body parts—say, a thigh or shoulder.

Learning to deal with stress and strain is a cornerstone of mental training—one that ideally begins well before a crisis. The possible consequences of constant pressure to perform—experienced today by almost every top athlete—are readily apparent. Fear of failure, inadequate recovery time and unending media harassment are fatiguing, especially for younger, less experienced competitors. When it appears these athletes are at the breaking point, that of course is usually when coaches call in a psychologist. But often it is too late. Many coaches call for expert help only when a situation is already critical. Studies indicate that more than two thirds of all interventions by sports

RON VESELY Getty Images

psychologists are done during times of acute problems and crises. Instead of putting out fires, coaches should consider ongoing care, so mental problems can be caught and treated early, before performance suffers.

Say It

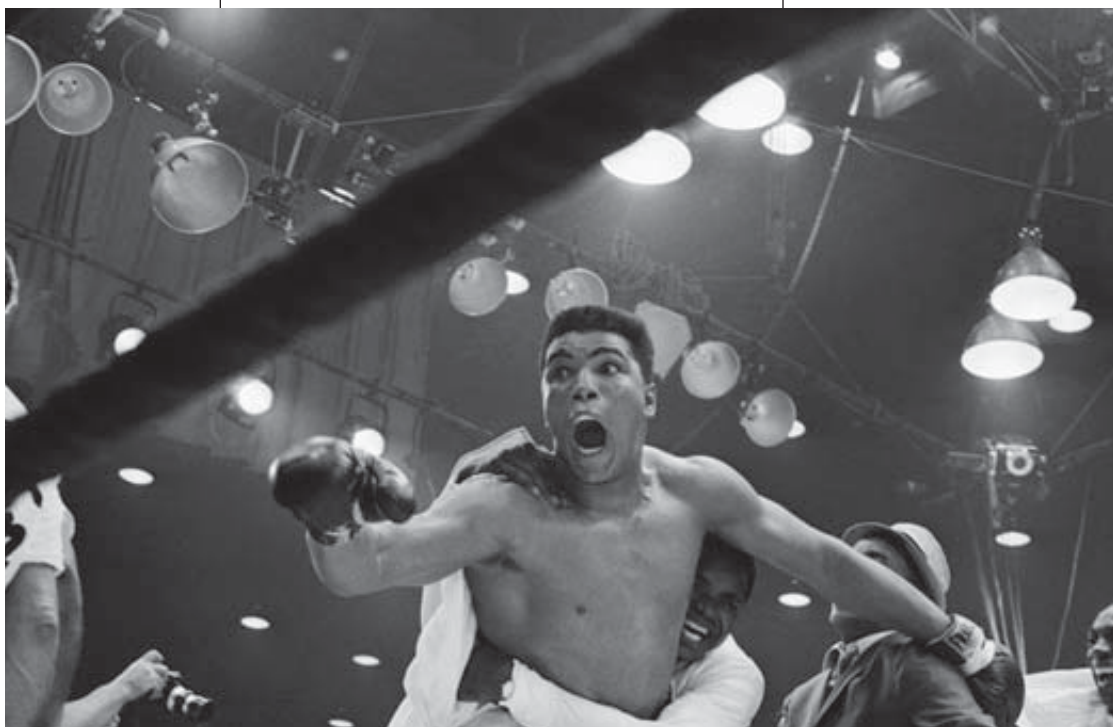
Nevertheless, some anxiety is unavoidable, and that may not be bad. Coaches often tell their players that a little nervousness is good because it keeps them on their toes. Too much anxiety limits performance, however. Self-talk is a leading method for reducing doubt and anxiety. Boxer Muhammad Ali, who strutted around before every match loudly proclaiming, “I am the greatest!” is probably the most famous practitioner of this technique. Such directed speaking increases one’s will to endure.

The value of self-talk was demonstrated in a classic 1977 sports psychology study. Michael Mahoney, then at Pennsylvania State University, working with coach Marshall Avenier, asked a group of gymnasts what they thought about and what they said to themselves during competitions. It turned out that the most successful athletes—those who qualified for the Olympic team—were no less plagued by doubt and anxiety than their less successful colleagues. But they compensated better by constantly encouraging themselves, more so than those who finished with lower scores.

The need for self-encouragement is highest in sports where winning is determined by subjective judges, such as gymnastics or figure skating. There is no clear order of finish like that in a 100-meter dash or a cycling race. Success in team sports is measured by “softer” criteria, too. Individuals can play well, and the team can still lose. The team needs a strong sense of collective identity. A soccer team, for example, must consist not of 11 individuals but of 11 friends.

A recreational athlete can exploit the same mental tricks that the pros use, whether it is talking to oneself for motivation, believing in one’s abilities to induce command of the game, or visu-

alizing one’s movements to optimize flow. And more and more amateurs are indeed resorting to mental gymnastics to help them push their own limits. Of course, the fitness industry is quite happy to jump on this bandwagon. Many dubious figures now bill themselves as “mental coaches”



or “motivational trainers,” even though neither title is based on any kind of recognized certification or degree.

A qualified mental coach will begin a serious sports psychology workup with a diagnosis of the current situation. On what level is the athlete competing? What are her problems, wishes, goals? Only then can appropriate methods be found to improve concentration, coordination or endurance. Through it all, however, athletes must keep one hard fact in mind: physical fitness and mastery of technique and tactics are the overwhelming determinants of success in any sport. No one has ever won a marathon through mental training alone.

Steve J. Ayan is an editor at Gehirn & Geist.

Proclaim:
Muhammad Ali
chanted, “I am
the greatest!”
to psych out
opponents and
to psych up
himself.

(Further Reading)

- ▣ **Flow: The Psychology of Optimal Experience.** Mihaly Csikszentmihalyi. Perennial, 1991.
- ▣ **Psyched Up, Psyched Out.** Michael Shermer in *Scientific American Presents: Building the Elite Athlete*, Vol. 11, No. 3, pages 38–43; Fall 2000.



FINDING

The human positioning system helps us navigate an unfamiliar



OUR WAY

city and may underlie general memory and thought

By Hanspeter A. Mallot

“Drive 200 yards, then turn right,”

says the car’s computer voice. You relax in the driver’s seat, follow the directions and reach your destination without error. It’s certainly nice to have the Global Positioning System (GPS) to direct you to within a few yards of your goal. Yet if the satellite service’s digital maps become even slightly outdated, you can become lost. Then you have to rely on the ancient human skill of navigating in three-dimensional space.

Luckily, your biological finder has an important advantage over GPS: it does not go awry if only one part of the guidance system goes wrong, because it works in various ways. You can ask questions of people on the sidewalk. Or follow a street that looks familiar. Or rely on a navigational rubric: “If I keep the East River on my left, I will eventually cross 34th Street.” The human positioning system is flexible and capable of learning. Anyone who knows the way from point A to point B—and from A to C—can probably figure out how to get from B to C, too.

But how does this complex cognitive system really work? Researchers are looking at several strategies people use to orient themselves in space: guidance, path integration and route following. We may use all three or combinations thereof. And as experts learn more about these navigational skills, they are making the case that our abilities may underlie our powers of memory and logical thinking.

Grand Central, Please

Imagine that you have arrived in a place you have never visited—New York City. You get off the train at Grand Central Terminal in midtown Manhattan. You have a few hours to explore before you must return for your ride home. You head uptown to see popular spots you have been told about: Rockefeller Center, Central Park, the Metropolitan Museum of Art. You meander in and out of shops along the way. Suddenly, it is time to get back to the station. But how?

If you ask passersby for help, most likely you will receive information in many different forms.

A person who orients herself by a prominent landmark would gesture southward: “Look down there. See the tall, broad MetLife Building? Head for that—the station is right below it.” Neurologists call this navigational approach “guidance,” meaning that a landmark visible from a distance serves as the marker for one’s destination.

Another city dweller might say: “What places do you remember passing? ... Okay. Go toward the end of Central Park, then walk down to St. Patrick’s Cathedral. A few more blocks, and Grand Central will be off to your left.” In this case, you are pointed toward the most recent place you recall, and you aim for it. Once there you head for the next notable place and so on, retracing your path. Your brain is adding together the individual legs of your trek into a cumulative progress report. Researchers call this strategy “path integration.”

Many animals rely primarily on path integration to get around, including insects, spiders, crabs and rodents. The desert ants of the genus *Cataglyphis* employ this method to return from foraging as far as 100 yards away. They note the general direction they came from and retrace their steps, using the polarization of sunlight to orient themselves even under overcast skies. On their way back they are faithful to this inner homing vector. Even when a scientist picks up an ant and puts it in a totally different spot, the insect stubbornly proceeds in the originally determined direction until it has gone “back” all of the distance it wandered from its nest. Only then does the ant realize it has not succeeded, and it begins to walk in successively larger loops to find its way home.

Whether it is trying to get back to the anthill or the train station, any animal using path integration must keep track of its own movements so it knows, while returning, which segments it has already completed. As you move, your brain gathers data from your environment—sights, sounds, smells, lighting, muscle contractions, a sense of time passing—to determine which way your body has gone. The church spire, the sizzling sausages on that vendor’s grill, the open courtyard, the train station—all represent snapshots of memorable junctures during your journey.

In addition to guidance and path integration, we use a third method for finding our way. An office worker you approach for help on a Manhattan street corner might say: “Walk straight down Fifth, turn left on 47th, turn right on Park, go through the walkway under the Helmsley Building, then cross the street to the MetLife Building into Grand Central.” This strategy, called route following, uses landmarks such as buildings and street names, plus directions—straight, turn, go through—for reaching intermediate points. Route following is more precise than guidance or path integration, but if you forget the details and take a wrong turn, the only way to recover is to backtrack until you reach a familiar spot, because you do not know the general direction or have a reference landmark for your goal.

The route-following navigation strategy truly challenges the brain. We have to keep all the landmarks and intermediate directions in our head. It is the most detailed and therefore most reliable method, but it can be undone by routine memory lapses. With path integration, our cognitive memory is less burdened; it has to deal with only a few general instructions and the homing vector. Path integration works because it relies most fundamentally on our knowledge of our body’s general direction of movement, and we always have access to these inputs. Nevertheless, people often choose to give route-following directions, in part because saying “Go straight that way!” just does not work in our complex, man-made surroundings.

Road Map or Metaphor?

On your next visit to Manhattan you will rely on your memory to get around. Most likely you will use guidance, path integration and route following in various combinations. But how exactly do these constructs deliver concrete directions? Do we humans have, as an image of the real world, a kind of road map in our heads—with symbols for cities, train stations and



Your mission: return to Grand Central Terminal. First, you note a global reference to mark the general direction: the Empire State Building (top, spire). Then you backtrack, finding a path from one remembered, local landmark to the next: a crossing at 57th Street (middle), St. Patrick's Cathedral (bottom) ...

... the statue of Atlas at Rockefeller Center (top), a particular hot dog vendor (middle), and finally Grand Central appears (bottom). You have pieced together a route by navigating from snapshot to snapshot in your mind.



churches; thick lines for highways; narrow lines for local streets?

Neurobiologists and cognitive psychologists do call the portion of our memory that controls navigation a “cognitive map.” The map metaphor is obviously seductive: maps are the easiest way to present geographic information for convenient visual inspection. In many cultures, maps were developed before writing, and today they are used in almost every society. It is even possible that maps derive from a universal way in which our spatial-memory networks are wired.

Yet the notion of a literal map in our heads may be misleading; a growing body of research implies that the cognitive map is mostly a metaphor. It may be more like a hierarchical structure of relationships. To get back to Grand Central, you first envision the large scale—that is, you visualize the general direction of the station. Within that system you then imagine the route to the last place you remember. After that, you observe your nearby surroundings to pick out a recognizable storefront or street corner that will send you toward that place. In this hierarchical, or nested, scheme, positions and distances are relative, in contrast with a road map, where the same information is shown in a geometrically precise scale.

Behavioral evidence also undermines the idea of a literal mental map. For one, map reading is not particularly easy. Children have to work at learning the skill, and many adults can live for decades in a city without being instantly able to find their residence on a map. Sketching a map of even a familiar town is a challenge for many people.

Perhaps people are more like the desert ant, which appears to memorize only what is necessary for its immediate trip, without creating anything like a complete map. We may deal with our daily routes from home to office and office to café in a similar manner. The idea that humans and other animals rely primarily on a basic dead-reckoning approach to navigation attacks a widely shared prejudice among neurobiologists, who claim that mammals store spatial knowledge differently than lower animals. The conventional wisdom is that people create complex maps that include abstract entities and that are independent of the perspective of the person who is moving through a course—a kind of coherent overview that is in agreement with the coordinates of the real world. The ant knows only routes to and from its nest. It cannot take shortcuts from one foraging area to another—it must always go back to the nest first.

As they debate the extremes, researchers are homing in on a locational-memory model for hu-

AGE FOTOSTOCK (top); CATHERINE KARNOW Corbis (middle); MORTON BEEBE Corbis (bottom)

mans that lies somewhere between “map in the head” and “learn by rote.” Ranxiao Frances Wang of the University of Illinois and Elizabeth S. Spelke of Harvard University described such a model in 2002. Imagine, again, that you are on your first stroll through midtown Manhattan. As soon as you get off the train and as you wander, you take photographs of notable locations using a Polaroid camera. The first picture might show the hot dog vendor just up the block from the station, the second photograph a broad statue several blocks away, the next a striking cathedral one avenue over and so forth.

You number the snapshots as you advance, noting how you have gotten from one place to the next. If you walk down an unknown street and

its streets are laid out in hexagonal networks.

We asked test participants to observe a particular street in the town’s network, which appeared to them as it would at eye level if they were standing in the middle of an actual street. We then asked them to “walk” around Hexatown and try to remember their routes. In addition to routine structures along the streets, two types of distinctive landmarks were available: unique local buildings placed at branches of streets and global references such as background mountains and tall buildings that were visible in the distance.

We then shifted the relations among the visual imagery by rotating the town and local landmarks while keeping the global landmarks fixed. We asked subjects, starting from a single point

(A memory structure evolved for spatial orientation was later employed for other cognitive functions.)

reach a location that seems familiar, you can review your collection of snapshots; if you have an image of the place, you can write down how you got there from the last location you photographed. All the while, as you journey onward, your brain is busy collecting images of unique locations and imprinting the paths that connect them, step by step, creating a denser and denser network.

When it is time to return to the station, you search your memory for pathways from image to image, piecing together a route back to the first picture. Like the ant, you are remembering only items that matter. Yet to save time, you may skip a snapshot and devise a more direct path from your current spot to the place shown two pictures earlier; unlike the ant, you are making creative and flexible use of your memory for locations. You remember many places, many routes, and you can formulate complex paths among them. And yet, in principle, this locational-memory model manipulates just two elements: places and routes. The model is powerful yet simple.

Cruising Hexatown

To assess whether human locational memory works in the way just described, the research group with which I worked at the Max Planck Institute for Biological Cybernetics in Tübingen, Germany, devised a test to track how people navigate through a virtual environment. The subjects sit in front of a color monitor that displays a computer-generated city called Hexatown, because

on a virtual street, to indicate which way the route they had previously learned now went.

Almost none of the subjects caught on to the rotation or used that as a clue; they continued to rely on their previous orientation strategies to try to rerun the original route. Some participants followed local landmarks and chose the same direction as before; the fact that the mountain range and tall buildings now rose in different places did not bother them. Without realizing it, they had rotated along with the town. Other people continued to orient themselves using the unchanged global landmarks, which obviously led them down completely new routes. They also failed to notice that the local landmarks—houses, squares, trees—were not the same as the ones they had seen before.

Does this mean that each of us relies on only one type of landmark and may not even have access to the others? To answer this question, we removed either the mountains or the unique buildings at crossroads. With little trouble, the participants switched to the other set of cues to rerun their course.

Apparently, our test subjects could orient themselves using local or global landmarks but decided to use only one type if both were avail-

(The Author)

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Cognitive maps might resemble the Washington, D.C., subway map: a relative chain of landmarks for which exact distances, angles and proportions are unnecessary.

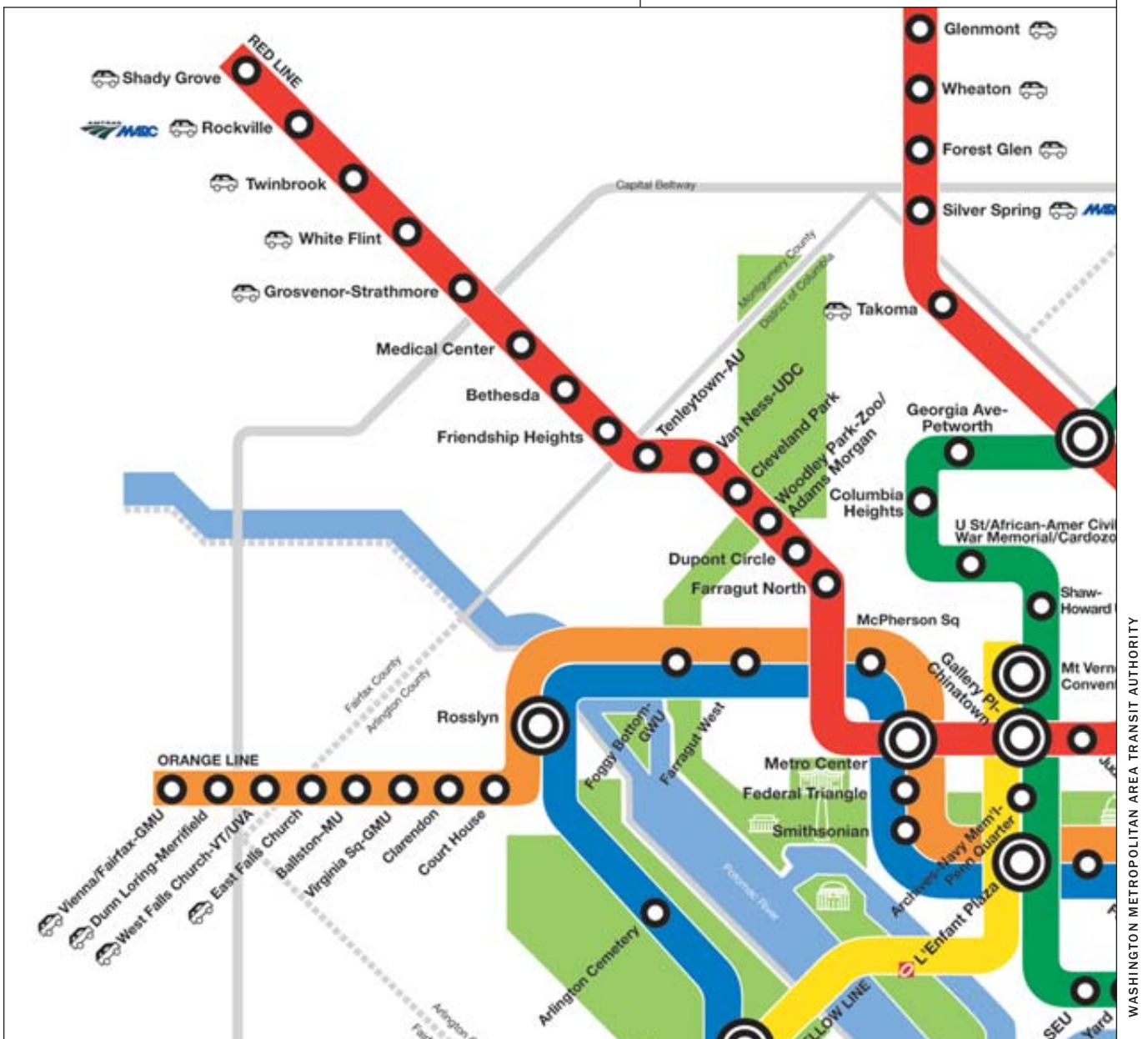
able. It is not clear, however, why they did not notice that the two sets of landmarks had been rotated in relation to each other. To complicate matters, when we pointed out the shift after the tests were completed, most of them argued, often vehemently, that the relations among landmarks had not been altered.

We have more research to conduct. For now, we can conclude that human locational memories contain many individual bits of information, but we do not check to see if they are consistent with one another. As a result, contradictory bits may stand side by side, without confusing us. This observation indicates that cognitive maps are not similar to real road maps, because physical maps must be coherent.

The Subway of All Thought

What might cognitive maps “look like” in our heads, then? Perhaps they are like a graph, a collection of points and connections—something like a subway map. The points, or nodes, represent the unique landmarks we notice, and the lines between them correspond to actions that get us from one node to the next.

Note that on a good subway map, like that for Washington, D.C. [see illustration below], exact distances and accurately angled turns are unnecessary. The map only approximates the proportions of individual stretches and directions and puts nodes only in relative relation to one another. Exact scale and geographic rigor would add extraneous details that needlessly confuse



WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

(It is easier to remember information if we can somehow see it as **connections among locations.**)

navigational needs. They also eat up lots of memory. And new lines can be added without having to adjust all the details of the entire map.

Using a mental graph akin to a subway map, we can easily advance along a chain of landmarks to navigate from start to finish. In Manhattan, when it is time to return to the train station, we can retrace a step-by-step route or devise a new way to move directly from point C to point A. We can use guidance, path integration or route following (or some combination) to reach our destination, and we do not have to burden our brains with details that do not help us advance on our course.

Humans have a multitude of cognitive maps in their heads. Our locational memory has not changed for millions of years—it has simply refined the original principle. Indeed, philosophers, scholars and brain researchers have long suspected that spatial orientation is more than a special skill—it may be one evolutionary root of memory or thought itself. For example, Cordula Nitsch and her colleagues at the University of Basel in Switzerland showed in experiments with gerbils that increasing levels of damage to the hippocampus, a deep and ancient brain structure, increasingly impaired both the animals' spatial orientation and memory retention in navigating a course they had previously mastered.

One good indication of the fundamental nature of spatial cognition in people's other mental abilities is the loci method of mnemonics, known since antiquity. Music students, for example, learn which notes fall on the spaces between lines of the staff by remembering the word "face"—the note F is on the lowest space, then A, C, E as the spaces rise. We remember telephone numbers by relating them to dates or mathematical formulas or the pattern they create on a phone's buttons. When we take notes, we write words but then draw circles and arrows that show importance and connections, clearly a map of ideas. We describe processes with block diagrams. It seems easier for us to remember information if we can somehow show it as connections among locations in an imaginary or real environment.

The fact that we typically memorize locations better than abstract items of information is not just a sign of the key role of locational memory for our general ability to make a mental note of objects in our surroundings. In the 18th century

philosopher Immanuel Kant had already listed the ideas of space, time and causality as the fundamental building blocks of human intelligence that did not stem from experience. According to Kant, humans simply cannot *not* think spatially. In the mid-1900s Nobel Prize-winning behavioral researcher Konrad Lorenz proposed that the complex three-dimensional environments of the first arboreal primates provided a strong impetus for the development of higher cognitive skills. And we see today that many of the idioms we use in daily speech have spatial roots: we "get oriented" to new situations, try to "find ways out" of our problems, and ask colleagues to "walk us through" proposed plans.

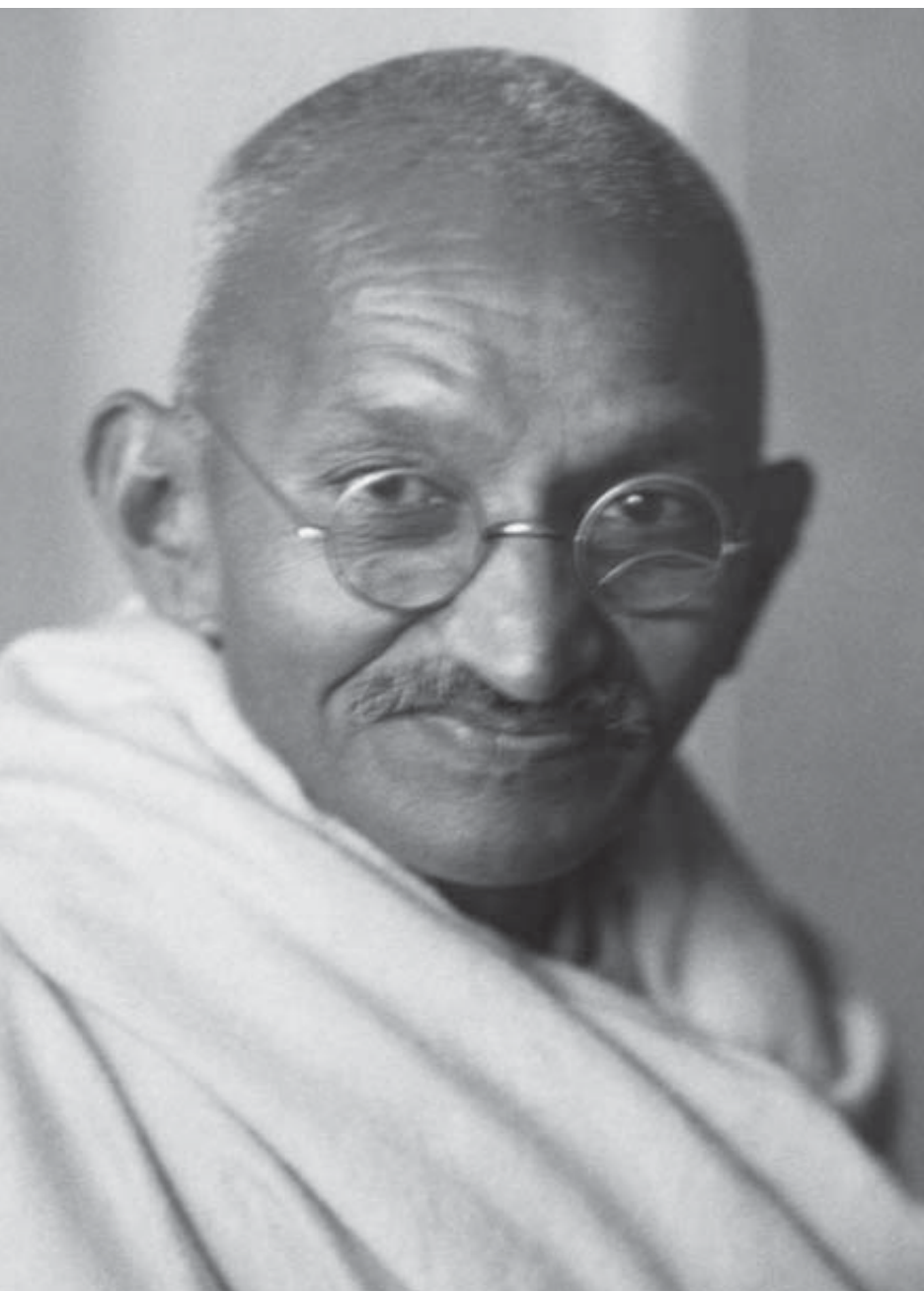
If spatial references readily transfer to non-spatial information, then the graph model can transfer to nongeographic tasks as well. To make a cake, you have to carry out a series of actions. You measure the ingredients, mix them together, fill the cake pan. Each step is a node, and the work you must do to get from step one to step two is the line connecting them. This baking graph is flexible and expandable. Some recipes call for eggs, which requires an additional step between "measure" and "mix"—specifically, cracking the eggs. You may have learned this skill in another context—making an omelet—but you add it to the cake-baking repertoire. In a similar way, a first-time visitor to Manhattan adds segments to his or her graph of how to get around from information gleaned from other contexts—the sun rises in the east, which indicates north, and a shop owner notes that Central Park is north, up Fifth Avenue, from Grand Central Terminal.

It is not inconceivable that over the course of human evolution a memory structure developed for spatial orientation—one that was later employed for other cognitive functions. The uses to which lower animals apply spatial cognition implies as much. Or to put it more provocatively: in the animal kingdom, spatial cognition is the most widespread form of thought.

(Further Reading)

- ▮ **Human Spatial Representation: Insights from Animals.** Ranxiao Frances Wang and Elizabeth S. Spelke in *Trends in Cognitive Sciences*, Vol. 6, No. 9, pages 376–382; September 2002.
- ▮ **Human Spatial Memory: Remembering Where.** Edited by Gary Allen. Lawrence Erlbaum Associates, 2004.

FRIEND *OR*



You're entering a train car, a restaurant, a local store. As you step inside, you scan the people there. You don't know any of them, yet in seconds you register impressions of them all. He looks friendly, she appears evasive, that teenager seems threatening. Even as you're assessing the factual cues of their bodies—gender, skin color, height, age—you already seem to know whom you perceive as likable and whom you should avoid.

The fact that our brains can reach such rapid conclusions is astounding. It is also troubling: despite the paltry information available to the brain in those initial moments, our first impressions can color our continued perception of an individual, regardless of whether his or her later words and actions contradict our hasty preliminary view.

To make such social perceptions, we rely on patterns and stereotypes that we have learned throughout our lives. For example, when we see a man driving a lavish car, what impression do we have of him: a rich show-off or a self-made achiever? If we see a teenage girl struggling to handle a crying baby, do we see an ill-prepared mother or a babysitter? We pull out dozens of labels from our heads and apply them to other people.

Our social perception is constantly ac-

HULTON-DEUTSCH COLLECTION Corbis (Gandhi and Hitler)

How we instantly size up people has little to do with logic and a lot to do with looks By Marion Sonnenmoser

FOE?

tive, too. We can't turn it off. And we place it in high regard; when we are making decisions, it is often the factor that tips the scales, although we may not even be aware that it is affecting us. Social perception strongly determines everything—from whom we fall in love with to whom we trust to sell us insurance. In every case, how well we like the person plays a major role. But why do we find certain people instantly likable while we mistrust others?

Beauty Favored

The process by which we “decide” whom to like is less open than we would prefer to think. We tend to follow some persistent prejudices. Twenty years ago, for example, University of Massachusetts Boston psychologist S. Michael Kalick demonstrated that we generally favor faces, body shapes and clothing styles that are similar to our own. And although it sounds shallow, we are significantly influenced by beauty. When assessing members of the opposite sex, at least, our hearts warm more readily to people who have been blessed with flawless skin, flowing hair, straight teeth, and a well-proportioned and slender figure. Evolutionary psychologists think we are attracted to these characteristics in part because they send positive signals to our pri-



Baby-face hypothesis: men may be more attracted to women like model Claudia Schiffer (right) who have a small nose and high forehead—childlike features that appeal to protective instincts.

mal brain circuits responsible for choosing a mate: “I’m healthy. I have strong genetic traits!”

Ironically, when our brains do take the time to think critically, excessive perfection can elicit mistrust or inferiority or jealousy. Often in court proceedings, very attractive defendants are given harsher sentences if it appears they used beauty as a means to an end. Nevertheless, studies of different social situations agree that our brains automatically react positively to attractive people.

Emotion over Logic

Of course, we have all had bad experiences with attractive people. These encounters reveal a major weakness in social perception: that preconceived notions can lead us to poor decisions. We are seldom aware of these prejudices, however, which gives them power over us. They are persistent and hard to overturn. Tania Singer and Joel S. Winston of the University College London’s



Institute of Neurology reached that conclusion when they showed test subjects portraits of various people. Some of the faces elicited immediate alarms in the amygdala—a structure near the brain’s center that is considered the seat of emotion—indicating that the individuals pictured “did not inspire trust.” Yet when the subjects were told later about the good qualities of the people they had seen, few indicated that the information changed their initial impression.

Psychologists have been researching social perception for decades, but it is only recently that brain imaging and electrical sensing techniques have begun to elucidate its biological roots. “Social neuroscience” is still a young discipline, but discoveries are helping experts decipher what makes us judge a stranger as friend or foe.

(The Author)

MARION SONNENMOSER is a psychologist at the University in Landau in Germany and a freelance science journalist.

For example, visual signals from the eye’s optic nerve travel to two brain regions: the forebrain, where conscious thought occurs, and the amygdala. Both regions evaluate what we see, but in completely different ways. The amygdala first makes a determination of friend or foe—within milliseconds, automatically and independently. The forebrain comes into play only after the amygdala has made its determination, and it is influenced by that assessment as it consciously categorizes and assesses the visual information.

The effect of this dual processing was tested by neuropsychologist William A. Cunningham, now at the University of Toronto, and his colleagues. He placed each of 15 subjects in a magnetic resonance imaging machine. To each of them, he read aloud the names of famous people, such as Bill Cosby, Yasir Arafat and Mahatma Gandhi. The subjects were instructed to respond to a neutral question (“Is he alive or dead?”) and an emotionally driven question (“Is he a good or bad person?”). The images showed that the subjects answered the first question with ease. In the second case, Cunningham observed a considerable increase in the amygdala’s activity, especially in connection with names that carried negative connotations, such as Adolf Hitler. Yet the forebrain showed approximately the same level of activity as it had during the neutral question, irrespective of whether a name elicited a positive or negative image. In essence, the amygdala cast the deciding vote on whether to declare someone good or evil. Emotional assessment outranked cognitive assessment.

Among its other duties, the amygdala functions as a danger detector, activated by potential threat. Its rapid response can instruct us whether to react with fight or flight. In pioneering work in the 1990s, Joseph LeDoux of New York University showed that angry human faces elicit stronger responses in the amygdala than known threats themselves, such as snakes. Recently Ahmad R. Hariri of the National Institute of Mental Health imaged the brains of 28 subjects while they viewed photographs of faces with angry or fearful expressions. Hariri also showed them pictures of snakes, sharks and guns. Both sets of pictures elicited a significant response in the amygdala, but its reaction to threatening faces was stronger.

The Social Brain

The more active the amygdala becomes, the more intense our emotional upheaval and the more our capacity to reason decreases. Decisions are made intuitively rather than as a result of rational assessment.

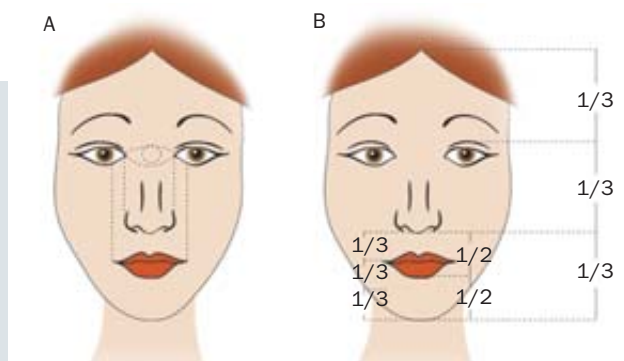
GETTY IMAGES (left); MITCHELL GERBER Corbis (right)

Face It

Beauty is a matter of personal taste. Yet psychological studies have found that people tend to respond favorably to certain patterns of facial features when seeing a person for the first time.

Several factors make a face “attractive.” Highly asymmetrical faces tend to be off-putting. But if a face’s symmetry (A) is too perfect it somehow leaves a boring impression. Small variations make a face lively and interesting. And although race and ancestry play a part, characteristics such as high cheekbones, small nose and ears, certain proportional distances between the eyes, nose and mouth (B), and a smooth, clear complexion register as attractive. A strong chin is considered desirable in men, whereas women with large eyes and full lips are thought to be prettier.

Often men consider women to be attractive when the faces have childlike features, such as a small nose and high forehead. Although most volunteers in several experiments on this “baby-face hypothesis” have been Cau-



casian, researchers think this physiognomy appeals to an adult male’s protective instinct or to his subconscious assessment that a woman who looks young has many fruitful reproductive years. But other patterns are also thought to be beautiful and, in many cases, by one sex more than the other. Men may be attracted to women with high cheekbones and full lips, traits considered to exude sexual magnetism. It is not clear that women find these features attractive in other women.

Women tend to be better than men in judging the character of others, as well as expressing empathy for them. The reason, says British psychologist Simon Baron-Cohen of the University of Cambridge, is that from childhood on, girls are instructed to be sensitive to the feelings of others and to offer consolation when warranted. This type of socialization helps to hone senses, intuition and observational skills.

Women are also more likely to make decisions based on “gut feeling”—or better yet, on “amygdala feeling.” And finally, women draw on their language centers more than men. As a result, women are often better at verbalizing and therefore have an easier time in gaining emotional access to other people.

Baron-Cohen and a growing number of neuroscientists contend that the left brain contains actual “social brain regions” that enable the brain to accurately perceive other people. According to Baron-Cohen, the left brain develops much faster in female fetuses and babies, as well as in young girls, establishing a lifelong advantage in language and social intelligence.

Compared with men, women are also thought to use the sense of smell more when deciding on a person’s likability. In 2002 experimental psychologist Pamela Dalton of the Monell Chemical Senses Center in Philadelphia proved that females have a much more discerning nose than males. Once again, the amygdala plays the deciding role in assessing olfactory information. Scent is therefore closely connected to emotional reactions. Psychol-

ogist Noam Sobel of the University of California at Berkeley found that the amygdala reacts strongly not just to foul odors but also to pleasant smells. Sobel thereby supports Cunningham’s claim that this structure could be responsible for spontaneous feelings of attraction and for choosing a mate, as well as for fear and antipathy.

Follow Your Nose

Regardless of how important smell, language and the social brain are, the lesson is that we establish important reactions and make many important decisions based not on precise thinking but on feelings of attraction or rejection.

Nature has developed a system for quickly figuring out whether a stranger is friendly or threatening. This system operates without the intervention of the intellect. The downside is that we cannot escape its function. The amygdala and the social brain manipulate us whether we want them to or not. Of course, our forebrain and conscious reasoning have input and can veto assessments. But when it comes to emotional questions, perhaps we modern, thinking people should put more trust in our sniffers, which have been perfected over thousands of years.

(Further Reading)

- **Neural Components of Social Evaluation.** William Cunningham et al. in *Journal of Personality and Social Psychology*, Vol. 85, No. 4, pages 639–649; 2003.
- **Blink: The Power of Thinking without Thinking.** Malcolm Gladwell. Little, Brown, 2005.

Classical neuroscience holds that the brain's right hemisphere processes the emotions behind faces and voices, while the left hemisphere handles the facts involved. Or not **By Steve J. Ayan**

GETTY IMAGES

al lives? The German team designed several experiments to pursue an answer.

Visible Emotions

The team exposed test subjects to a variety of stimuli, such as emotion-laden images or words, while their brain activity was measured. The researchers used a combination of probes, including the common electroencephalograms (EEGs) that sense brain waves; magnetoencephalography, which measures magnetic fields produced by the brain during neural activity; and functional magnetic resonance imaging (fMRI).

As a first step, psychologist Markus Junghöfer of the University of Constance showed healthy subjects photographs of neutral, disturbing and exciting scenes. He flashed images on a screen more than 200 times in rapid succession. This pattern did not give the brain enough time to “think” about what it was seeing, only to react.

The upshot was that barely 200 milliseconds after a flash, emotionally charged images triggered a strong EEG signal from the visual cortex in the back of the brain. The more charged the picture was, the stronger the signal, regardless of whether the images depicted an attacking snake or naked men and women engaged in sex.

The experiment verified what other researchers have proposed for some time—that the limbic system responds to extreme sights before the sensory information perceived by the eyes even reaches the visual cortex [see “Friend or Foe?” by Marion Sonnenmoser, on page 78]. In doing so, the amygdala instantly rivets our attention on potentially important stimuli. The team’s fMRI images supported this conclusion as well. From an evolutionary standpoint, such lightning reactions of “motivated attention” provided the ability to escape danger or quickly kill for a meal.

The Right Tone

The same flurry of images also brought to light another finding: the reactive brain signals were considerably stronger in the right hemisphere than in the left. Conventional wisdom would say this imbalance occurred because the neuronal networks responsible for attention and spatial orientation are located in the right hemisphere. But what happens when the same test subjects are confronted with emotional words? In most people, the language-processing regions are in the left hemisphere. To check, the researchers at Constance read out loud a series of neutral, positive and negative adjectives to the volunteers. Once again, they found very quick brain respons-

es, but in this trial the left side was dominant.

Thus far the team had verified by experiment what had been expected in theory. It now wanted to see if more complex stimuli followed the straightforward patterns. Neurologist Dirk Wildgruber of the University of Tübingen designed tests that relied on the intonation of language rather than on its plain content, because *how* a person says something often transmits more emotional information than *what* he says.

Wildgruber had test subjects listen to recorded sentences such as “I’ve been visiting Agnes every weekend.” This sentence was spoken by an actor in a voice that was happy, frustrated or neutral. A computer then processed the sentences so that they differed only in terms of sound amplitude and vowel length. These traits were enough for the subjects to distinguish the intensity of the emotional expression.

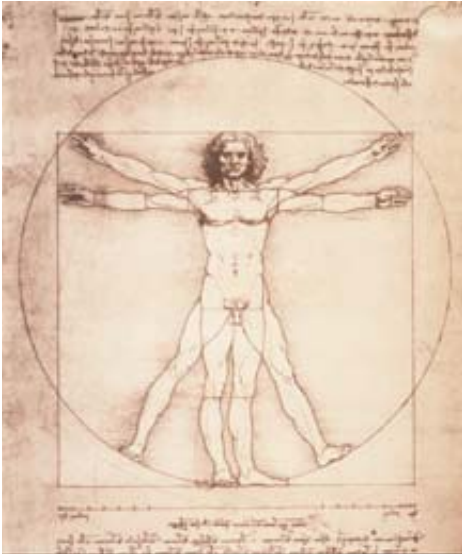
The fMRI images showed that the emotional coloration inherent in tone stimulated two cortical regions—one in the frontal lobe and one in each of the parietal lobes—but it did so more markedly on the right side. Differentiating intonation was the result of numerous small contributions from both hemispheres. This conclusion gave the researchers much to ponder. Suddenly, the question of whether the right hemisphere is primarily responsible for emotions could not be answered clearly. Which hemisphere takes the leading role seems to depend not just on which sense is stimulated (vision or hearing) but also on the nature of the stimulus (tone versus words).

The team will further probe this puzzle in 2005, in part by studying unusual emotional processing by certain psychiatric patients who are emotionally unstable. Gabriele Ende of the Central Institute of Mental Health in Mannheim is already looking at people who are suffering from depression, who seem to be less able to recognize the feelings of others.

There is still much to learn about how humans process emotional inputs. But it appears that the popular notion of an “emotional” right hemisphere that contrasts sharply with a “rational” left hemisphere is like a crude pencil sketch made before a full-color painting: many nuances are waiting to be added. Emotional communication involves so many brain regions and connecting channels that the right hemisphere hypothesis has only limited validity.

(Further Reading)

□ National Institute of Mental Health’s Center for the Study of Emotion and Attention: www.php.ufl.edu/csea



Leonardo da Vinci, Neuroscientist

Five centuries ago the artist-engineer leaped past his contemporaries in developing a more scientific understanding of the brain

By Jonathan Pevsner

The archetypal Renaissance man, Leonardo da Vinci draws wide admiration for his unequaled range of intellectual passions. The creator of the *Mona Lisa* and other artistic masterpieces in the second half of the 1400s and early 1500s was also an accomplished musician, entertainer, scientist and engineer whose inventions included ball bearings, instruments to measure the specific gravity of solids, and fantastic war machines (although he abhorred the “most bestial insanity” of battle).

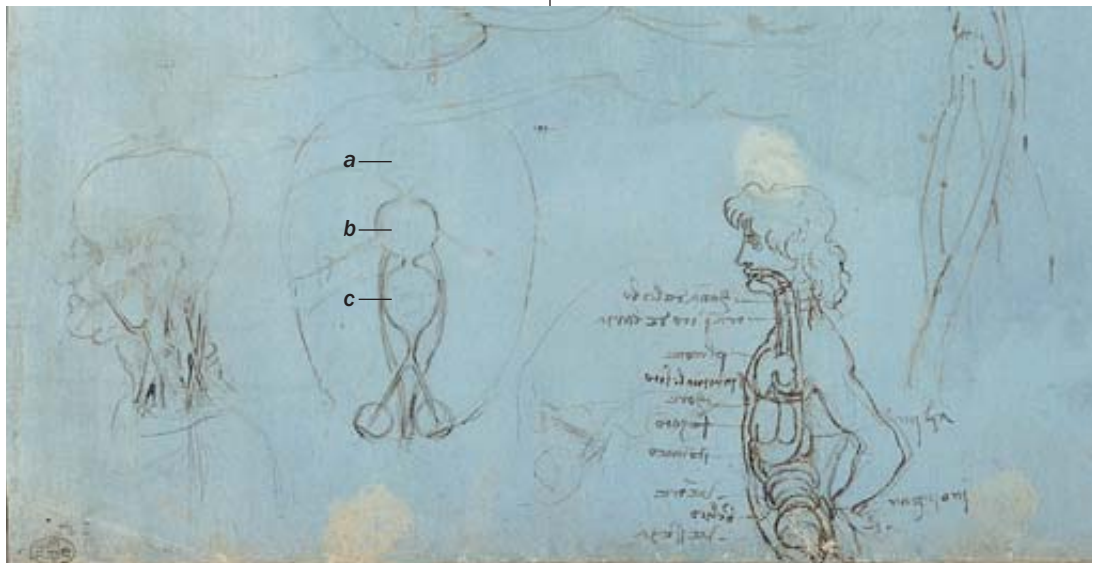
Less well known—largely because hundreds of his pages of notes and detailed anatomical drawings went unpublished until the late 19th and early 20th centuries—are his remarkable and penetrating findings in neuroscience. In an era more comfortable accepting notions handed down from medieval science and ancient Greece

and Rome, he pioneered the practice of sketching anatomical features based on his own direct observations. He also strove to establish a physical basis by which the brain interprets sensory stimuli and through which the mind functions. And he developed a coherent theory of how the senses operate, in particular how the eye sees—mechanistic explanations of such phenomena that reflect the thinking typical of his primary career, engineering.

Leonardo’s studies of physical form (above) also went below the surface, to structures in the brain (opposite page). The mirror writing compares the layers of an onion with those of a skull. The depiction of the three oval ventricles is inaccurate but follows the teachings of the time—the artist later broke with such conventions.



Leonardo drew ventricles in the brain that he believed housed memory (a); thought and sensory integration (b); and the processing of sensory impressions (c).



Leonardo never went to university and only began studying Latin in his 40s. As he wrote, “my works are the issue of pure and simple experience, which is the one true mistress.” As a keen student of nature, Leonardo stands apart from most of his contemporary anatomists, who tended to regurgitate the dogma of earlier Greek and Roman authorities—from the school of Hippocrates to the teachings of Galen. Yet he was not entirely unfettered by his era’s reliance on the past. The views common in his day also shaped—and sometimes confounded—his efforts to understand the structure and functions of the brain.

Foundation of Life

Leonardo was born on April 15, 1452, near Vinci, some 20 miles from Florence. As a teenager he joined the workshop of Andrea del Verrocchio in Florence, and at age 20 he was admitted to the Company of Painters. Artists in Renaissance Florence were encouraged to perform, or at least observe, dissections. Leonardo’s paintings such as the *St. Jerome*, composed around 1480, indicate that he had gained knowledge of human musculature. But little evidence suggests that he performed autopsies or displayed a deeper interest in anatomy until later in the 1480s, when he moved to Milan. There his relentless curiosity would lead him to a striking series of discoveries in the fields of neuroanatomy and neurophysiology.

Leonardo’s earliest surviving anatomical drawings are related to the nervous system and date from circa 1487, when he pithed a frog (pierced its spinal column). He may have been the first person to perform this experiment. He

wrote: “The frog instantly dies when its spinal medulla [medulla oblongata] is perforated. And previously it lived without head, without heart or any interior organs, or intestines or skin. Here therefore, it appears, lies the foundation of movement and life.” Leonardo loved animals: he was a vegetarian, was known to buy birds at the market to set them free, and was an avid enthusiast of horses. Perhaps for this reason none of the rest of his many hundreds of experiments recorded vivisection.

On the same sheet with the frog, he sketched the spinal cord and added the words “generative power,” reflecting the belief, which had originated 1,900 years earlier with the famed Greek physician Hippocrates, that sperm derive from the spinal cord. Next to the spinal cord, Leonardo drew a tube, with a caption that said that the sense of touch was the cause of motion and the “passage for animal powers” (*transito della virtu animalia*).

Leonardo might have been exposed to the ideas of animal spirits through the writings of Galen of Pergamum (roughly around A.D. 130 to 200), the greatest physician of the ancient Roman era. After Galen’s death, progress in anatomy stalled for eight centuries, until the rise of Islam. Galen described a concept first developed by a physician from the famous medical center at Alexandria, Erasistratus of Ceos (who flourished circa 300 B.C.). Erasistratus believed that air breathed in is converted to “vital spirit,” which is conveyed to the brain’s ventricles, where it becomes “animal spirit.” This animal spirit filled the hollow nerves and enabled them to control the movement of muscles. (Today we understand that nerve cells are not hollow and that they

propagate an electrical signal to the nerve terminal, where chemical neurotransmitters are released across the synapse, a small gap between the neuron and muscle cell. These chemical transmitters induce a muscle cell to contract.)

Turning to Leonardo's early drawings of the brain, we find a remarkable page dated to approximately 1487 [see illustration on page 85] showing a cross section of an onion and several drawings of the human head with schematic views of the eye. Beside the images, he wrote: "If you will cut an onion through the middle, you will be able to see and enumerate all the coats or rinds which circularly clothe the center of this onion. Similarly, if you will cut through the middle of the head of a man you will first cut the hairs, then the scalp, then the muscular flesh and pericranium, then the cranium; and inside, the dura mater, the pia mater and the brain; then again the pia mater and dura mater and the rete mirabile and then the bone, their foundation." This text was derived from Ibn Sīnā (also called Avicenna, who lived from A.D. 980 to 1037), a Persian philosopher and physician who grew to prominence comparable to Galen's, largely through his encyclopedic *Qanun fi-al-tibb* (*Canon of Medicine*). The

in Latin. (Our phrase "common sense" derives from this term.) Most authors placed fantasy and imagination in the *sensus communis* as well. The middle ventricle housed *cogitava*, *ratio* or *estimativa*—what we call rational thinking. Ibn Sīnā's *Qanun* explained that the *sensus communis* in the anterior ventricle receives sensory information, the imagination holds the sensory perceptions after they have subsided, and the cogitative faculty in the middle ventricle can manipulate images stored in the imagination—creating the idea of a flying man or an emerald mountain, for example. Most authors agreed that the posterior ventricle was the seat of memory.

In many dozens of medieval and Renaissance manuscripts, we find diagrams in which the *sensus communis* is depicted in the anterior ventricle, such as Leonardo indicates in the illustration on page 85. But Leonardo modified his views in a dramatic contrast to the prevailing dogma, transferring the *sensus communis* to the middle ventricle and now labeling the anterior ventricle "*imprensiva*." The word "*imprensiva*" is difficult to translate, and no anatomist before or after Leonardo has used this term. It refers to a site for the processing of sensory impressions, in partic-

Because he based his theories of the mind on physical laws, he was sometimes led in unexpected directions.

Qanun formed one of Leonardo's principal sources.

Leonardo's depiction of the skull includes the frontal sinus, shown as a protrusion just above the eye, which is one of his original discoveries. The optic nerve projects from the eye toward the center of the brain, encountering the first in a row of three oval ventricles—they look quite different from the actual appearance of these cavities filled with cerebrospinal fluid. Leonardo's ventricles also appear in a view from above, which shows the optic and auditory nerves entering the anterior ventricle.

What inspired Leonardo to draw the brain's ventricles this way? Galen had localized cerebral functions, including sensory and motor output, to brain regions near the ventricles. Galen's interpreters subsequently introduced the doctrine of three ventricle "cells," ascribing various brain functions to them. An anterior cell was thought to serve as the common meeting place for all the senses, and hence it was called *sensus communis*

ular visual input. Thus, he continued to show the optic nerve terminating in the anterior ventricle. The olfactory and auditory nerves entered the middle ventricle, which was labeled *senso comune* or sometimes *comocio* (thought) or *volonto* (will).

Leonardo's unique labeling of the ventricles reflects the tremendous importance he accorded to the sense of vision, which he described as the window to the soul and the most important basis of all experience. To him, the role of the artist was to depict nature—"the painter's mind must of necessity enter into nature's mind in order to act as an interpreter between nature and art"—and this role primarily involves vision. Unlike any other artist or anatomist, Leonardo equated artistic perception with an anatomical framework for seeing, and it is extraordinary that he places emphasis on the visual system above other senses as acting through the *imprensiva*. He believed that once information passed to the *senso comune* it was judged, and he thought of this

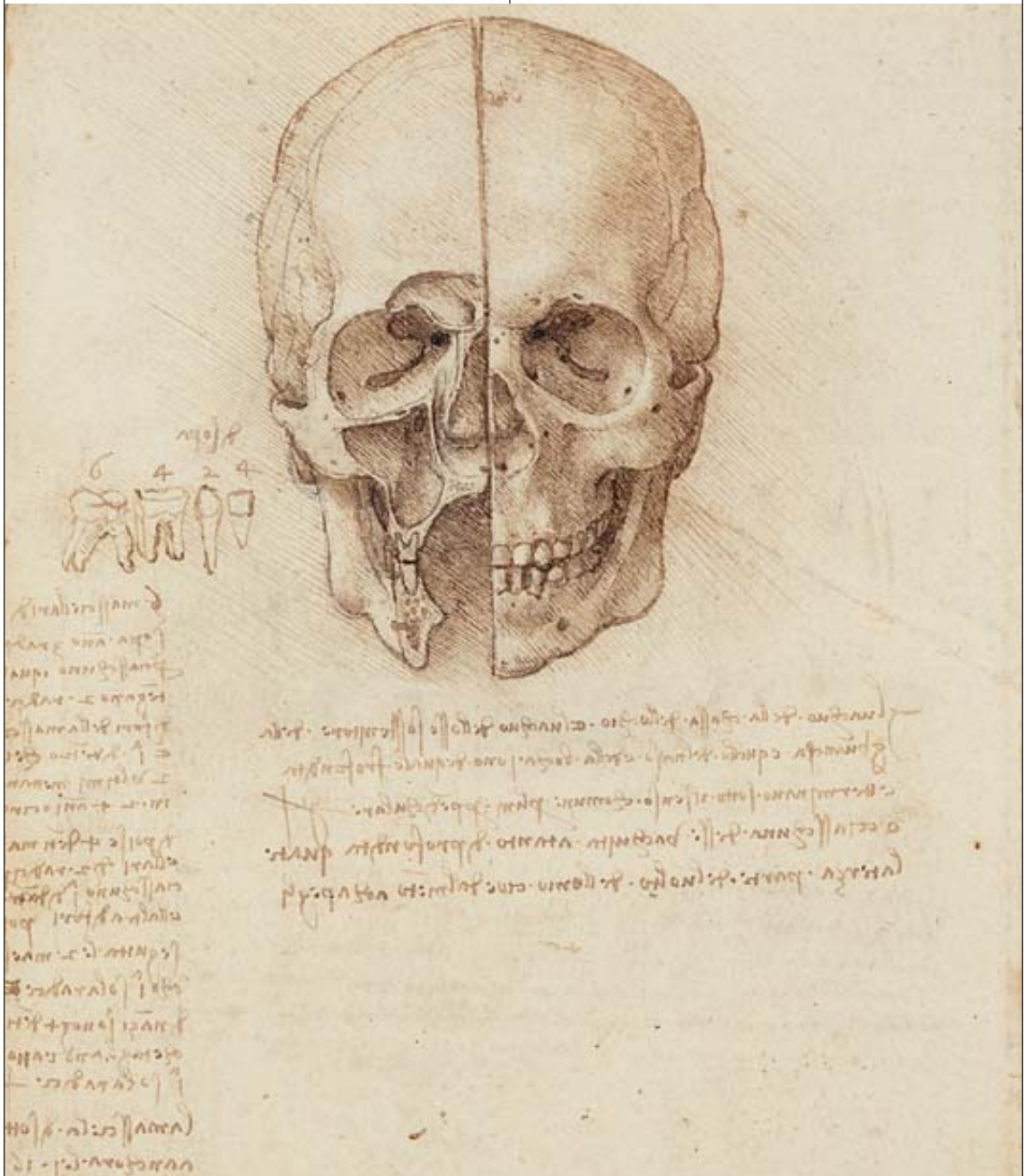
function as an inner eye or *occhio tenebroso* (“the eye in shadows”—that is, the eye without external light).

Between 1487 and 1493 Leonardo went on to create a number of marvelous drawings of the skull. These beautiful, lifelike images are among his most inspired anatomical works. In one [see illustration below], we see a skull divided down the middle, allowing a view of multiple depths. On the left side is the maxillary antrum, a cavity in the facial area, which Leonardo was the first to identify. The accompanying text concerns the location of the *senso comune* relative to the face, as well as a discussion of the number of teeth.

(Leonardo corrected Aristotle, who had suggested that men have more teeth than women.)

Another anatomical tour de force [see illustration on opposite page] provides the first accurate depiction of the meningeal arteries; the blood supply to the brain was significant to Leonardo as the source of “vital spirit” to the ventricles. This diagram also shows the cranial nerves leading to the geometric center of the brain, where Leonardo located the *senso comune*. The nerves do not in reality converge in this way, so Leonardo’s arrangement followed what he thought should be, rather than what he had actually observed.

Split view of the skull shows the maxillary antrum, a cavity in the facial area that was discovered by Leonardo.





Drawing shows the first accurate depiction of the meningeal arteries, which supply blood to the brain. It also shows cranial nerves converging in the brain's center—an idealized, not actual, location.

Locus of the Soul

To Leonardo, the judging of information by the soul also took place in the *senso comune*. “The soul seems to reside in the judgment, and the judgment would seem to be seated in that part where all the senses meet; and this is called the *senso comune*,” he wrote circa 1489. “All our knowledge has its origin in our [sense] perceptions,” he concluded. Visual objects, smells and sounds converge on the *senso comune*, while “perforated cords” convey sensory information from the skin.

Leonardo invoked a military metaphor to explain how motor output is also controlled by the *senso comune* and the soul. As he put it, “The nerves with their muscles obey the tendons as soldiers obey the officers, and the tendons obey the *senso comune* as the officers obey the general. Thus, the joint of the bones obeys the nerve, and the nerve the muscle, and the muscle the tendon, and the tendon the *senso comune*. And the *senso comune* is the seat of the soul, and memory is its ammunition, and the *imprensiva* is its standard of reference because the sense waits

on the soul and not the soul on the sense. And where the sense that ministers to the soul is not at the service of the soul, all the functions of that sense are also wanting in that man’s life, as is seen in those born mute and blind.” Leonardo’s interest in the soul often turned to such questions of disease. He wrote: “How nerves sometimes operate by themselves without any command from other functioning parts of the soul. This is clearly apparent, for you will see paralytics and those who are shivering and benumbed by cold move their trembling parts such as head or hands without the permission of the soul; which soul with all its forces cannot prevent these parts from trembling. This same thing happens with epilepsy

(The Author)

JONATHAN PEVSNER is a lifelong student of Leonardo and frequently gives lectures on him. He is an associate professor in the department of neurology at the Kennedy Krieger Institute and in the department of neuroscience at the Johns Hopkins University School of Medicine. In the laboratory, he studies childhood brain disorders such as Down syndrome and those caused by lead poisoning. Pevsner has also written a textbook on bioinformatics, the combined field of molecular biology and computer science.

In later work, Leonardo progressed to where he drew what he saw, not what he had been taught to see, yielding greater accuracy.



and with severed parts such as the tails of lizards.”

Because Leonardo based his theories of the mind on physical laws, he sometimes was led in unexpected directions. For instance, he argued at length that ghosts cannot exist: “There can be no voice where there is no motion or percussion of the air; there can be no percussion of the air where there is no instrument; there can be no instrument without a body; and this being so, a spirit

can have neither voice nor form nor strength.”

After 1493, Leonardo set his anatomical studies aside for about 15 years. He stayed in Milan through the 1490s, working as an entertainer in the court of Ludovico Sforza, engaging in artistic projects such as the *Last Supper*, performing civil and military engineering, and writing his treatise on mechanics called the *Elements of Machines*. In 1505 he continued his earlier stud-

ies of the flight of birds and the possibilities of human-powered airplanes and gliders. His focus on mathematics sharpened as he tried to apply the science of perspective to his painting. His efforts were shaped by an obsessive desire to understand what he called the four powers of nature: movement, weight, force and percussion.

Leonardo's belief in the body as a mechanical instrument subject to these four powers led him

in a naturalistic way how the nerves cross over at the optic chiasm. All these cranial nerves no longer entered the ventricles, as they had in the traditional illustrations, but instead traversed the surrounding brain tissue. Leonardo had progressed as an anatomist to the point that he drew what he saw, even when it contradicted the enormous weight of authority.

Leonardo performed his experiments on the

(Despite challenges, Leonardo made enormous strides in one lifetime.)

to impressive innovations when he returned to the topic of anatomy. Consider his studies of the heart. He was the first to realize that the organ has four chambers, not two, and he discovered the atria (what he called the two "upper ventricles"). He correctly surmised that the atria contract to propel blood. During an autopsy, he even identified an atrial septal defect, a hole in the septum separating the two atria. He made a three-dimensional glass cast of the aorta to study its function and performed detailed investigations (including glass models) of the tricuspid, pulmonary, mitral and aortic valves. He discovered the moderator band, a muscle spanning the right ventricle.

And so when Leonardo again took up his explorations of the structure and function of the brain, around 1508 to 1509, his approach was built on a sounder background than his initial studies had been. He invented a brilliant technique: after drilling a hole in the base of the brain of a dead ox, he used a syringe to inject hot wax into the ventricles. When the wax set, he cut away the brain tissue and thus made a reasonably accurate cast of the ventricles. This is the first known use of a solidifying medium to measure the size and shape of any internal body structure, and it provides an example of how Leonardo used his training as an artist—in this case, as a sculptor—to develop a new scientific approach.

Leonardo proceeded to make an impressive drawing of a human head, this time depicting the ventricles in more realistic shapes based on what he had observed in the ox [see illustration on opposite page]. Equally astute was his positioning of the cranial nerves. We can identify seven pairs, including the olfactory nerves, which had never before been described as cranial nerves, and the optic nerves. He was the first to diagram

brain in a broader context of his studies on the nature of sensory stimuli and the function of the eye. He maintained a largely traditional theory of how the eye detects images of things we see. Light, he believed, is a "power" that carries visual rays from an object to the eye in the form of "pyramids" that meet the eye at the top of the pyramid. Waves of "percussion" pass through the pupil and lens down the optic nerve to the *impressiva* and then to the *senso comune*, where they enter consciousness. Having read the literature regarding optics and then performed his own experiments, Leonardo struggled to the conclusion that we see objects because the eye receives light. This view was in opposition to those espoused by Plato, Euclid, Galen and others, who held that visual power emanated from the eye, although it was supported by some, including the great Arab philosopher and physicist Alhazen.

Despite such challenges, Leonardo made enormous strides in one lifetime. If he could travel forward in time to visit our society, he would surely marvel at our further progress in understanding the brain's physical functions through the use of observation and experimentation. At the same time, he might be surprised to learn how many of the questions he posed still remain incompletely addressed by modern neuroscience: How is it that we read or remember? Why do some people have mental retardation or epilepsy? Why do we dream or even sleep? What is the soul? Thanks in part to the foundations laid by Leonardo and others, perhaps we will have answers within the next five centuries.

(Further Reading)

- ▣ **Leonardo da Vinci's Elements of the Science of Man.** Kenneth Keele. Academic Press, 1983.
- ▣ <http://pevsnerlab.KennedyKrieger.org/leonardo.htm>

Small acts that create immediate pleasures can add up to long-term satisfaction **BY MAJA STORCH**

Make Yourself Happy

LITTLE EVENTS sometimes have far-reaching consequences. For example, the reason I'm no longer driving a delightful but temperamental Alfa Romeo is because of a chocolate Easter bunny. I used to bring my car to a repair shop that employed a mechanic with whom I was most pleased. Then one day he phoned to inform me that he had resigned. "But why?" I asked him. "A new owner has taken over," he replied. "The working atmosphere isn't like it used to be. I just didn't feel good there anymore."

Immediately the psychologist in me was intrigued. "So what was different?" I wanted to know. "Well, I guess it was just little things," he said. "Like, at Easter, the owner's wife would always slip a chocolate bunny into everyone's toolbox. It made you feel like someone out there was making an effort." The Easter bunny didn't come anymore, the esteemed mechanic left, and my next car was a reliable but less glamorous Saab.

Behind this trivial story lurks a central topic of psychology: how per-

sonal happiness originates. Psychologists hope that once we understand this, we might be able to create these feelings at will.

Short-Term Joys

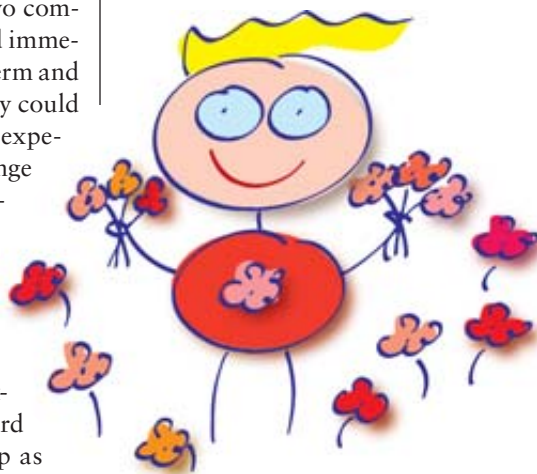
Personal happiness has two components: one is short-lived and immediate, and the second is long-term and "habitual." The instant variety could best be described as an intense experience of joy. These feelings range from sensual pleasures to so-called flow experiences—brought on by acts in which we become totally immersed and lose all sense of self. Instant happiness can also emerge when you are just relaxing on your balcony after a hard day's work, with your feet up as you watch the sun go down. Short-term pleasures create a stirring of emotions that psychologists refer to as positive affect.

Many people can motivate themselves before beginning an unpleasant task by anticipating the good feeling of success they will get when the job is completed. And simple acts of social caring can create positive affects for others: a smile, a word of praise, a kind letter—or a chocolate Easter bunny.

Most individuals underestimate the power this factor can have in both their private and professional lives. One extravagant annual company picnic does not create a healthy working environment; it takes many immediate, smaller happy moments to achieve this atmosphere. All employers should demonstrate to their employees that they care. Even if employers are focused only on the bottom line, for only minimal time and expense they can noticeably increase job satisfaction and, therefore, productivity. The same

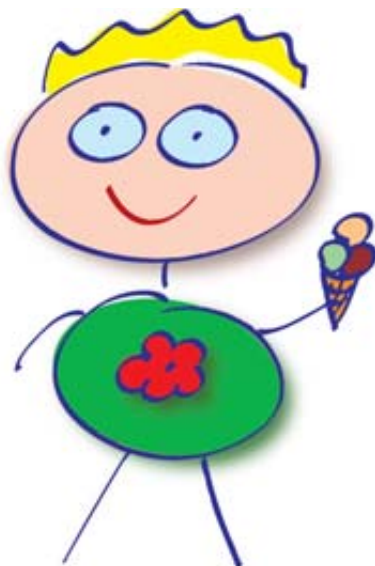
applies to family relationships and partnerships. Each person—alternating each week, for instance—can take a turn "being responsible" for positive feelings by bringing home flowers, getting tickets for a movie, or planning a weekend outing together.

A very different tactic can also elicit immediate feelings of happiness—the reduction of anything that makes



you unhappy. Let us say you are in a meeting at work at which another employee shoots down one of your proposals with an unannounced set of statistics. Because he did not submit his figures before the meeting, you have not prepared a reply. Everyone is impressed with his pie chart, even though you are sure no one really understands it. You are overtaken by a wave of anger, and, worse, you can think of nothing to say.

To dissipate the unhappiness that will most likely stay with you after such a meeting, you can use a device we have developed at the University of Zurich called the idea basket. Imagine that there is a basket in front of you and that you are going to fill it with suggestions from your colleagues and friends. Begin by making a detailed list of which situations, circumstances and triggers have led to specific negative emotional experiences. Then ask as many trustworthy and discreet



By becoming aware of your somatic markers, you can build a foundation of positive thoughts.

people as you can to come up with appropriate ways to respond.

Try to get ideas from people in as many different social groups as possible. Certainly ask your favorite co-worker, but also approach your son's kindergarten teacher, the neighborhood bricklayer, even your 14-year-old daughter—despite her adolescent behavior that sometimes leaves you wondering how sound her thinking really is. Often those whose minds have stored experiences through very different connections produce the most surprising and helpful ideas. Once your suggestion basket is full, choose several options that could reduce the negative aspects and then resolve to act on them. Even if you cannot fully transform the negative into a positive in a given situation, curing it even halfway can greatly improve your happiness.

Long-Term Satisfaction

By creating an ongoing series of short-term highs and reversing lows, you are already on your way to long-term, habitual happiness. This state expresses itself as an all-encompassing feeling of satisfaction with life. According to psychological surveys, factors that can strongly contribute to this state are financial security, a well-ordered social environment and a trusting relationship. And yet many people experience a “dissatisfaction dilemma”—they just do not feel happy even when they have in place favorable life circumstances, such as the ones just mentioned. The way to resolve the dilemma is to squeeze into each day as much immediate happiness as possible. By using every opportunity to feel happy, you awaken positive feelings that can buoy your spirits.

Here are just a few possibilities:

- In the morning, become aware of the rising sun; at breakfast deeply

inhale the fragrance of your coffee.

- While riding to work on the train, watch the landscape rather than pointlessly rifling through papers from the office.
- When you get to work, greet your co-workers with a “good morning” before you check your e-mails.
- After an hour or two, take a small break; you will feel better, and it will improve your concentration on the next task as well.
- Buy a flower during lunchtime and beautify your desk.

There is only one important rule here: the more the better. It is the number of such happiness motivators that count—not their quality. Many seemingly trivial acts add up to the joy of living.

You can also stimulate long-term satisfaction intellectually. If you main-

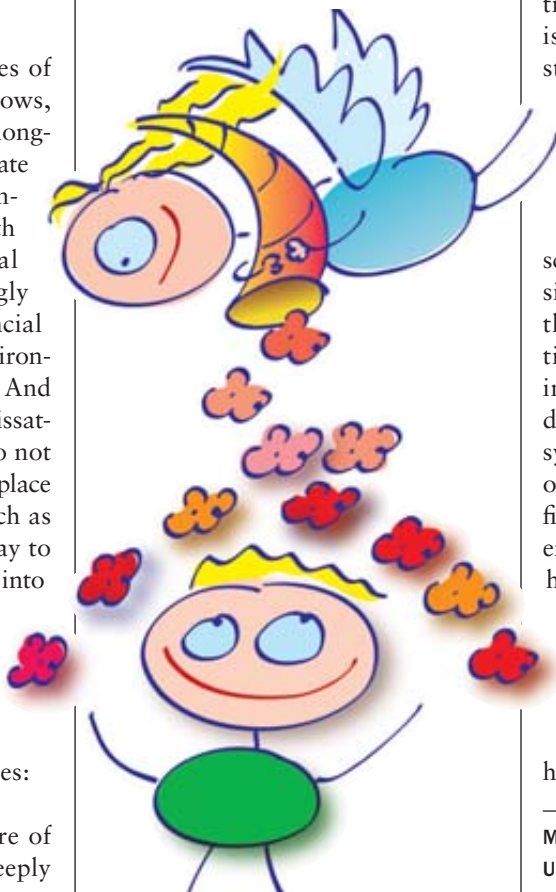
tain positive thoughts, you will indeed start to feel happier. This is not to say that habitual happiness can be grounded in figments of the imagination. It must be based on a solid foundation, which means fulfilling your desires, hopes and expectations as best as you can. But to do so, you first have to know what you want. On this score, somatic markers can help.

Scientists now know that sensory information is under permanent scrutiny by an automatic, internal process that promptly monitors experiences that pour in from our external world. The ability of an individual to know what is good for him or her is relative to how carefully the person can perceive and heed this internal commentary of somatic markers. Such markers are perceived either as a physical sensation or as a feeling, or a mixture of both. They originate in our emotional memory of experiences, which is a group of brain structures that store and evaluate every meaningful moment we have gone through.

Bad experiences send out negative somatic markers; pleasant ones produce positive signals.

You can train yourself to be consciously aware of your somatic-marker signals. By doing so, you will build that intellectual foundation of positive thoughts. In the long run, only individuals who have the self-confidence to guide their lives by their own system of values, regardless of public opinion or fashionable trends, can find true satisfaction. Somatic markers can provide invaluable guidance, helping you make the right decisions, realize long-term goals, and find the necessary motivation to transform your resolutions into action. In the process, you will create the preconditions that ensure long-term happiness.

MAJA STORCH is a psychologist at the University of Zurich.



Scientific Whydunit

A Cultural History of Causality: Science, Murder Novels, and Systems of Thought

by Stephen Kern. Princeton University Press, 2004 (\$29.95)

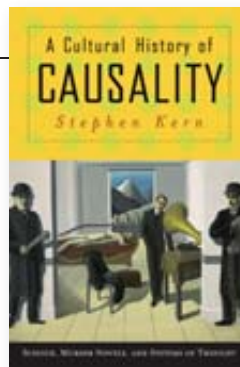
Did you forget to take “Quantum Physics and the Murder Novel” your senior year? If so, Kern’s book on causality will guide you through a daunting yet enlightening survey of how science has affected literature.

By “murder novels,” Kern does not mean whodunits. His focus is on the “whydunits” written by Victorian and modern writers: books that revolve around murder but dwell on their characters’ motives, not crime solving. Science comes into play because of the revolution in thought and knowledge between the period 1830 to 1900 and the 20th century. Over these years, Charles Darwin and Gregor Mendel revolutionized biology, Sigmund Freud revolutionized psychology, and physicists changed

our view of the universe.

The result, Kern says, is reflected in these novels: the protagonist of Émile Zola’s *Germinal* (1885) kills because of a murderous rage inherited from distant ancestors—“an explanation,” Kern writes, “that is unlikely in a serious modern novel.” In *Compulsion* (1956), however, Meyer Levin has killers driven by childhood sexual trauma, a cause of psychosis unknown before Freud. Although Kern cites more than 100 novels, he concentrates on a dozen or so exemplary authors, with Charles Dickens, Victor Hugo and Fyodor Dostoyevsky as leading Victorians and Theodore Dreiser, Franz Kafka and Albert Camus as modern thinkers.

Kern’s central idea is the “specificity-uncertainty dialectic.” Roughly summarized: the more specific information scientists gained about the world, the more they realized how little they knew. For example, geneti-



cists in the 20th century learned about genes and had a far better understanding of inherited characteristics than Victorians had—but the very breadth of this knowledge made the idea of a character inheriting an instinct a laughable notion.

Kern, a humanities professor at Ohio State University and expert on intellectual history, has mastered the novels, the critical literature, and the works by philosophers and sociologists bearing on his thesis. His descriptions of the genetics, neuroscience and physics that influenced writers are much briefer but accurate. *A Cultural History of Causality* is structured like a college course and can be heavy-going. But readers familiar with the novels will see them in a new light and—who knows?—scientists may be drawn by the connections Kern reveals to read these tales of murder.

—Jonathan Beard

Mind Reads

Sex and Learning

Why Gender Matters: What Parents and Teachers Need to Know about the Emerging Science of Sex Differences

by Leonard Sax. Doubleday, 2005 (\$24.95)

When I was a college freshman, a male teaching assistant I sought help from told me matter-of-factly that women were not good at inorganic chemistry. Had I been armed with *Why Gender Matters*, about how biological differences between the sexes can influence learning and behavior, I could have managed an informed rejoinder to go along with my shocked expression.

Sax—a pediatrician and psychologist in the Washington, D.C., area and founder of the National Association for Single-Sex Public Education—hopes to make today’s teachers and parents aware of the science behind differences between girls and boys. He was inspired to write the book as more and more parents brought their young sons to his office in the mid-1990s, seeking an evaluation for attention-deficit hyperactivity disorder. Recalling studies that show boys do not hear as well as girls, Sax felt that for some of the boys he assessed, simply not hearing the teacher led to their inattention, a problem that could be solved by a front-row seat.



Although Sax repeatedly makes clear these differences do not limit what either sex can achieve, he does contend they play a valuable role in determining the most effective methods for teaching, disciplining and understanding children and young adults. Using studies as well as anecdotes from his practice and visits to classrooms, he offers advice on such topics as preventing drug abuse and motivating students. In his chapter on aggression, Sax cites research that shows young male primates are much more likely to engage in rough-and-tumble play than females to illustrate why some amount of aggression in boys is normal and why banning “healthy” outlets such as dodgeball—done in his local school district—is misguided.

The book is thought-provoking, and Sax explains well the science behind his assertions. His anecdotes are generally instructive, although some are a little too thin to support his points. Sax ends by offering several compelling arguments in support of same-sex education, such as analyses that find girls are more likely to study physics and boys are more likely to study literature in single-sex schools. But whether or not you agree with Sax, his volume is a worthy read for those who care about how best to prepare children for the challenges they face on the path to adulthood.

—Aimee Cunningham

Wreckage of Psychoanalysis

13 Dreams Freud Never Had: The New Mind Science

by J. Allan Hobson. Pi Press, 2005 (\$24.95)

"One Saturday morning," Hobson writes, "I had two incredible dreams, in which I was kissing." Hobson, a psychiatrist and neurophysiologist who has researched sleeping and dreaming at Harvard University for decades, goes on to describe a disembodied mouth beckoning him, "wide open in a most lascivious fashion." This image, he reminds readers, refers to what Sigmund Freud would have called the dream's manifest (versus latent) content. And yet Hobson uses this personal remembrance, like many in his latest book, *13 Dreams Freud Never Had*, to explain how sequences of "regional brain activation" can account for a dream's quasi-delusional, almost psychotic qualities—without resorting to psychoanalytic interpretations.

As a physician who began his career treating patients in Boston's most horrendous psychiatric ward, Hobson has strived for 40 years to pay homage to Freud for initiating the brain-based study of mind—and yet also to set dream research free of a "superstitious and religious fixation on psychoanalysis." Hobson's research focuses on the organic aspect of dreaming that makes possible a dream's psychoslike features, including disorientation, visual hallucination and memory distortions. By measuring neural activity during dreaming, he and his colleagues have correlated brain-activation patterns with dream content, enabling them to show that much of a dream's form and substance derive from physiological processes that occur independently of a dream's apparent



meaning. Raw emotions and recent memories may trigger a dream, but not necessarily in a way that yields to clear, rule-based interpretations. Along with many current neurophysiologists, Hobson sees a dream's apparent meaning as an after-the-fact attempt to synthesize and put into story form an otherwise meaningless pattern of neural activations, most likely prompted by recent events rather than deeply rooted conflicts.

Not accidentally, Hobson's entertaining tale itself has a dreamlike quality—an autobiographical tapestry woven from strands of science, history and life in which he journeys through 13 of his own

350 dream reports, accumulated during his career. In each case, he uses a dream to make a point—usually how events in his life had most likely stimulated particular brain regions that subsequently were reactivated during a dream. He also weaves through his story recent research to explain the operations of a unified "brain-mind," emphasizing that the mind is a product of brain structure and chemistry, and nothing else. On the heels of half a century of modern neuroscience, he says, "it is now possible to build a new dynamic psychology on the solid base of brain science."

Hobson says Freud was "correct in assuming that any scientific psychology needed to be brain-based. But lacking that base, he was forced to speculate, and I have found that his contribution to a science of the mind is, at best, obsolete and, at worst, misleading." Imagining Freud's reaction to recent research, Hobson envisions the illustrious psychologist admitting that "the time has come to clear the decks of the wreckage of psychoanalysis and build a new science of dreams based on what is now known about the brain."

—Richard Lipkin

Ethical Catch-up

The New Brain Sciences: Perils and Prospects

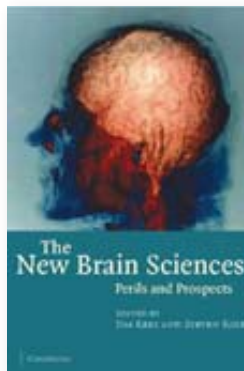
edited by Dai Rees and Steven Rose.
Cambridge University Press, 2004 (\$43)

What are the legal, ethical and moral implications of research in "the new brain sciences"? Rees and Rose, two distinguished British academics, invited the contributors to this collection of essays to ask hard questions about these subjects. Their answers will make you stop and think.

You might hope, for example, that decades of progress in psychiatry and psychology would be helping courts assess guilt, innocence and appropriate punishments. But contributor Stephen Sedley, a British judge who spent six years presiding over homicide cases, finds experts to be of little value. He admires the jury system because "of the rapidity with which twelve lay people were generally able to grasp and apply to a live problem before them principles of law." As for the testimony of psychiatrists, howev-

er, he says that he and the jury are typically left "peering into a very deep pool indeed with very little help about what was to be found there."

Perhaps the most visible of the new brain sciences is psychopharmacology, which has brought us drugs now taken by millions of people every day. John Cornwell, a historian of science at the University of Cambridge, writes from a courtroom in Louisville, Ky., describing a jury faced with "Prozac on trial." Weeks of neuroscientists' testimony left them baffled when they had to decide the case of a workplace killer who was on the antidepressant. But it is the elementary schoolroom, not the courtroom, that is the scene of today's largest-scale experiment in psychopharmacology. Over 2 percent of American schoolchildren now receive medication for attention-deficit hyperactivity disorder, writes Paul Cooper, a teacher and psychologist. "Medica-



tion should not be the default mode," he notes, yet increasingly it is, and in many cases, the drug serves to "treat" children who merely "experience difficulty conforming to the kinds of behavioral expectations that are common in schools."

Yet these thorny issues pale next to vexing medical issues that the new brain research may

raise. Readers are reminded that a neurologist won a Nobel Prize in 1949 for pioneering the lobotomy and that between the 1940s and 1960s surgeons cavalierly severed critical brain tissue in thousands of patients. Yadin Dudai, an Israeli neurobiologist, decries what he calls a new "lobotomy attitude" in neuroscience today, with researchers working toward "genetic manipulations, brain transplantations, even neurosilicon hybrids." He counsels "humbleness and patience" in view of how little we yet understand.

—Jonathan Beard

Match wits with the Mensa puzzler
BY ABBIE F. SALNY

Head Games

1 Despite the price of heating oil, make your way from COLD to WARM in exactly five steps on this word ladder. Change one letter at a time to make a good English word at each step.

C O L D

W A R M

2 A question is coiled in the grid below. To spell it out, start with one letter and move to an adjacent letter in any direction. (HINT: Start with a "W.")

W	H	F	E	E	N	I	N	H	C	H
A	S	F	R	E	C	H	C	A	T	A
T	T	D	I	B	T	T	C	N	A	N
E	H	G	T	E	W	A	E	D	F	C
W	E	I	H	E	E	N	A	N	A	E

3 The big store sales were on. Unfortunately, the \$100 fancy quilt wasn't selling. It was reduced by 40 percent but didn't sell. Then it was reduced 20 percent further, and it still didn't sell. Finally, it was reduced another 25 percent, and it sold. What did it sell for, and what percentage of the original amount was that price?

4 Jane has a number of quarters. She gives one fourth of her collection plus five quarters to her daughter Casey. She gives half of what is left plus five quarters to her friend Sally and then half of what is left plus five quarters to her pal Mary. Jane keeps 10 quarters for herself. How many did she have originally?

5 What three words, formed from different arrangements of the same five letters, can be used to complete the following sentence?

The tourist complained, "Those money changers are _____. They said, 'My _____ are equivalent to _____,' and they aren't."

8 Which one of the four words in the second line below goes best with the four words in the first line?

CATTLE	CANDLE	WONDER	CAPSTAN
ALWAYS	HAMBURGER	CHAIR	BEND

9 Figure out the pattern used in the first three circles and put in the missing number in the fourth circle.



10 If six painters can paint a total of six rooms in two days, how long will it take two painters to paint eight rooms?

Abbie F. Salny, Ed.D., was the supervisory psychologist for American Mensa (www.us.mensa.org/sciamm) and Mensa International (www.mensa.org) for more than 25 years. She is the author and co-author of many challenging puzzle books, including the Mensa Think-Smart Book and the Mensa 365 Brain Puzzlers Page-A-Day Calendar (Workman Publishing).

Answers

1. COLD, CORD, CARD, WARD, WARM.
2. "What's the weight difference between a thin chance and a fat chance?"
3. It sold for \$36. (36 percent of the original price of \$100.)
4. 100. (25 + 5 = 30, leaving 70; 35 + 5 = 40, leaving 30; 15 + 5 = 20, leaving 10.)
5. Hars, Itras, trials.
6. Category, catastrophie, catenary, catapult, cathedral.
7. Tweezers.
8. HAMBURGER. All the words on the first line begin with a three-letter word.
9. 12. (Subtract right from left and multiply this number by 4.)
10. Eight days. (Each painter can paint one room in two days.)

The brain, like nature, abhors a vacuum
BY VILAYANUR S. RAMACHANDRAN AND
DIANE ROGERS-RAMACHANDRAN

Mind the Gap

OUR PERCEPTION of the world depends, to a surprising degree, on intelligent guesswork by the brain. An oval-shaped white image exciting your retina could be produced by an egg, a perfectly circular, flat tilted disk, or an infinite number of intermediate shapes each angled to the right degree. Yet your brain “homes in” instantly on the correct answer. It does this by using certain unconscious assumptions about the statistics of the natural world—suppositions that can be revealed by visual illusions.

The manner in which the brain deals with inexplicable gaps in the retinal image—a process called filling

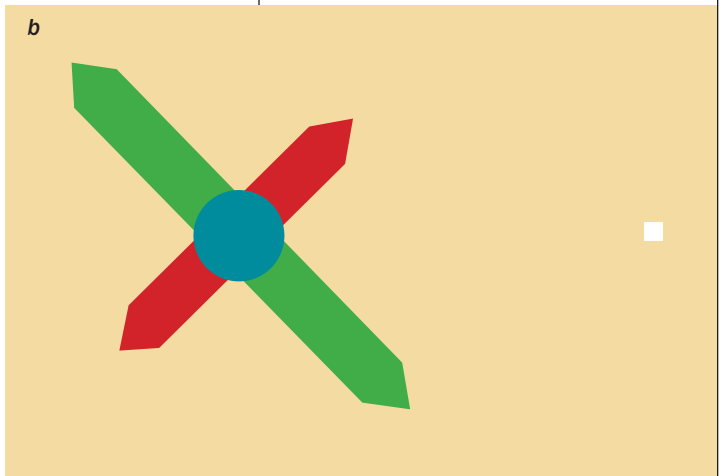
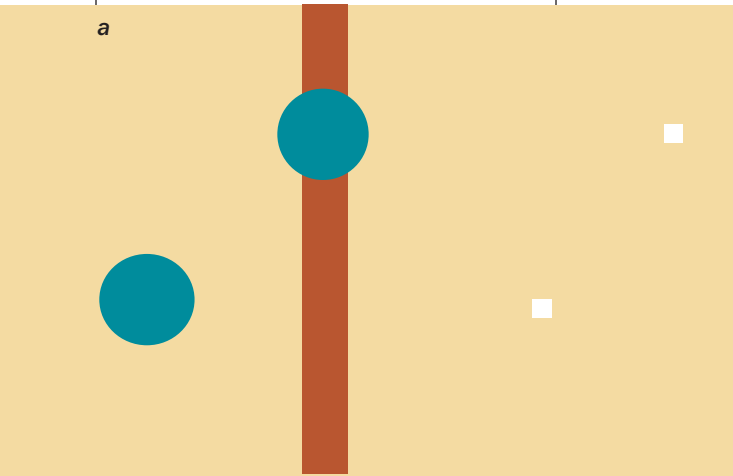
fection caused by the optic nerve piercing the retina as it exits the eyeball).

Victorian physicist Sir David Brewster was struck by how when the disk disappears, you do not experience a dark shadow or gaping hole in its place. The region corresponding to the disk is “filled in” by the background color. He attributed this process to God, the “Divine Artificer.”

Even a straight line running through your blind spot is not lopped off in the middle, as you can see by doing the same exercise but this time looking at the higher white box in (a). The missing segment of the line appears complete. It is as if the brain regards it as

then look around the room with your right. With some practice, you should be able to “aim” your blind spot on any small object to make it disappear from the visual field. King Charles II of England used to aim his blind spot on a prisoner’s head to “decapitate” him visually before an actual beheading. We often enjoy doing the same thing to rivals at faculty meetings.

How sophisticated is the filling-in process? If the middle of a cross falls on the blind spot, would it get filled in? What about repetitive wallpaper-like patterns? With just a few colored felt-tip markers and sheets of paper (or a computer graphics package), you



in—provides a striking example of this principle. You can demonstrate this using the blind spot of your eye.

Examine illustration (a). With the right eye shut, look at the center of the lower white box. Hold the page about a foot away from your face and slowly move it toward you and away from you. At a certain distance the disk on the left vanishes. It has fallen on the blind spot of your left eye, a small patch of retina called the optic disk that is devoid of receptors (an imper-

highly unlikely that two short lines could lie on either side of the blind spot simply by chance. So the cells in the visual centers fire just as they would if the bar had been complete, and you therefore see a continuous line. You can try coloring the two segments differently (for example, red and green) just for fun. Do you still complete the line?

The blind spot is surprisingly big, almost the size of nine full moons in the sky. Try closing your left eye and

can explore the limits of filling in and the “laws” that govern the process. I will describe a few examples here, but you can invent your own.

In (b), your blind spot falls on the center of an X made of a long green line crossing a short red one. If you are like most people, you will see that *only* the longer of the two lines is completed across the blind spot. (Whereas there is no difficulty filling in the missing part of the short line if it is

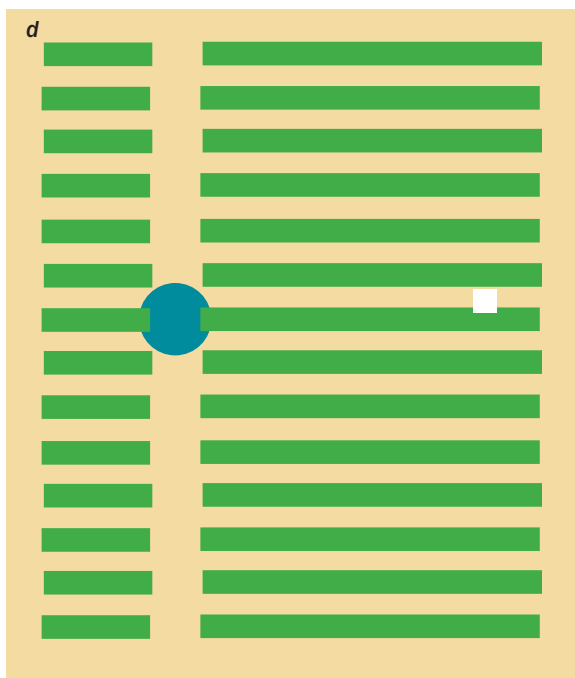
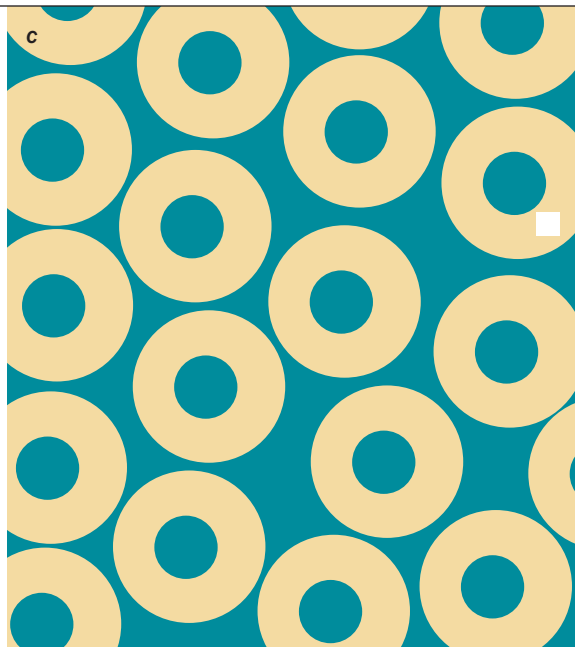
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presented on its own.) This simple exercise demonstrates that, under some conditions, filling in is based on integrating information along the whole length of the line rather than information that is spatially adjacent.

In other circumstances the brain fills in only what is *immediately* around the blind spot. If you aim your left eye's blind spot on the center of a yellow doughnut, you will see a yellow disk instead of a ring; the yellow fills in. Even more remarkable, the same thing happens in (c); most people see the yellow disk pop out conspicuously against a background wallpaper of yellow rings. Instead of extrapolating the repetitive ring patterns, your visual system performs a strictly local computation. It fills in just the homogeneous yellow immediately around the disk.

Yet this is not always true, as you will see from (d). Notice the vertical illusory strip running through the parallel horizontal lines. Aim your left eye's blind spot on the blue disk to make it vanish. Now the question is, Do you fill in the missing segments of horizontal lines running through the blind spot? Or do you fill in the vertical illusory strip? The answer depends on the spacing of the lines.

Why does filling in occur? It is unlikely that the visual system evolved this ability for the sole purpose of dealing with the blind spot (after all, the other eye usually compensates). Filling in is probably a manifestation of what we call surface interpolation, an ability that has evolved to compute representations of continuous surfaces and contours that occur in the natural world—even ones that are sometimes partly occluded (for example, a cat seen behind a picket fence looks like one whole cat, not like a cat sliced up). Physiologists (especially Leslie G. Ungerleider of the National Institute of Mental Health,



spot or by opaque occluders.

If you get bored playing with your natural blind spot, try this. Toward the right side of your TV screen tape a tiny (half a centimeter in diameter) bit of white cardboard with a black spot in its center. Next, turn the TV to a channel that isn't broadcasting so that you see just twinkling "snow." Affix a two-centimeter-square patch of thick gray cardboard (about the same color as the TV snow) 12 centimeters or so away from the white cardboard. Stand a meter away from the TV set. If you open both eyes and stare at the small black dot steadily for 15 seconds, the large gray square will vanish completely, and the region "vacated" by it becomes filled in with the snow—you hallucinate the snow where none exists! Remarkably, if you now look away at a gray wall, you will see a square patch of dots twinkling in the region where the filling in occurred. Even a solitary red blob seen against a background of green blobs will disappear in the same manner—the green blobs fill in. The brain, it would seem, abhors a vacuum.

These experiments show how little information the brain actually takes in while you inspect the world and how much is supplied by your brain. The richness of our individual experience is largely illusory; we actually "see" very little and rely on educated guesswork to do the rest.

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Ricardo Gattass of the Federal University of Rio de Janeiro and Charles D. Gilbert of the Rockefeller University) have now begun to explore the neural mechanism of this process by monitoring the manner in which single neurons in the visual centers respond to objects partially covered by the blind

(Further Reading)

▮ **Perceptual Filling In of Artificially Induced Scotomas in Human Vision.** V. S. Ramachandran and R. L. Gregory in *Nature*, Vol. 350, pages 699–702; April 25, 1991.