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Two astonishingly different persons inhabit our heads

We are left-brained or right-brained

By Maya Pines

Two very different persons inhabit our heads, residing in the left and right hemispheres of our brains, the twin shells that cover the central brain stem. One of them is verbal, analytic, dominant. The other is artistic but mute, and still almost totally mysterious.

This nonspeaking side of the human brain—the right hemisphere—is now the focus of intensive research by brain scientists. This sudden surge of interest is probably no accident at a time when Yoga, Arica, Tibetan exercises and other nonverbal disciplines are enjoying such a vogue. Some researchers are eager to give the less intellectual aspects of human personality equal weight with the verbal ones. But beyond this somewhat partisan approach lies the startling hypothesis that each of us is capable of two incompatible styles of thought, two separate mechanisms for learning.

In normal people, the two half-brains are linked together, like Siamese twins, by millions of nerve fibers that form a thick cable called the *corpus callosum*. If this cable is cut, as must be done in certain cases of severe epilepsy, a curious set of circumstances occurs. The left side of the brain no longer knows what the right side is doing, yet the speaking half of the patient, controlled by the left hemisphere, still insists on finding excuses for whatever the mute half has done, and still operates under the illusion that they are one person.

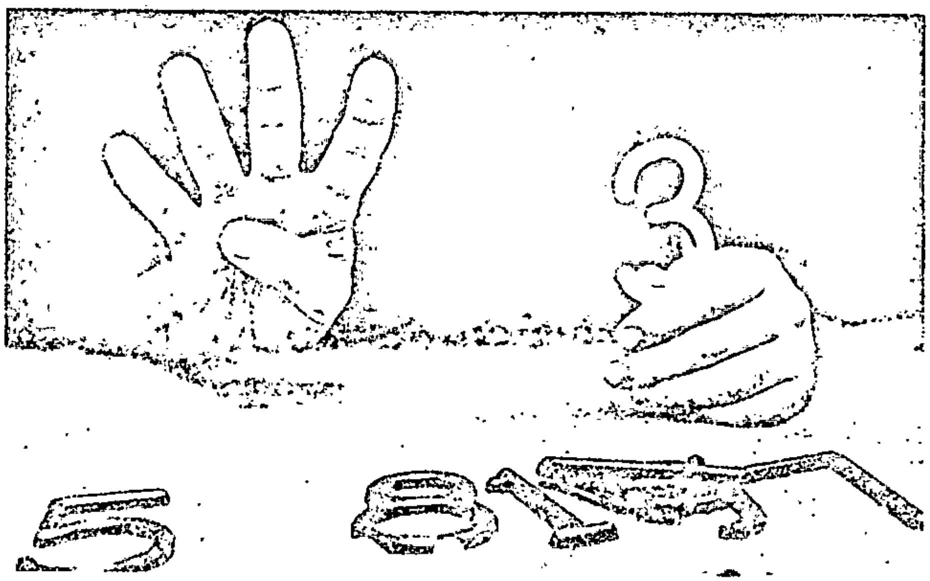
The findings of the past decade are extraordinary in their implications. Because of them, brain scientists have begun to wonder whether our normal feeling of being just one person is also an illusion, even though our brains remain whole. Are the two halves of our brains integrated into a single soul? Is one hemisphere always dominant over the other? Or do the two persons in our brains take turns at directing our activities and thoughts?

Theologians are watching this research with fascination—and some misgivings—and they are not alone. It has aroused the interest of many others who are concerned with human identity. As they soon realize, all roads lead to Dr. Roger Sperry, a California Institute of Technology professor of psychobiology who has the gift of making—or provoking—important discoveries.

Sperry was already famous before he began studying people and animals whose brains had been split in two. In a series of elegant experiments, he had shown that there exists a very precise chemical coding system during brain growth that allows specific nerve cells—for example, those concerned with vision—to find their way through a tangle of other nerve fibers, even when obstacles are placed in their path, and somehow connect with the appropriate cells so as to reach specific terminals in the visual cortex. Next, he began to study visual perception and memory. He wanted to find out what happened when an animal learned certain discriminations that involved the visual cortex—when it learned, for instance, to push a panel marked with a circle rather than a square. Where in its brain was that knowledge stored?

He put the question to a young graduate student, suggesting that he investigate how cats that have learned a new skill with only one eye and one hemisphere transfer this information to the other eye. The young student, Ronald Myers (now chief of the Laboratory of Perinatal Physiology at the National Institute of Neurological Diseases and Stroke), worked with this idea for the next six years. First he developed a method of cutting through the cats' optic chiasm (the point at which the optic nerves meet and cross) so as to sever the nerve fibers that normally cross from left eye to right hemisphere and vice versa, sparing only those that connect with the same side of the brain. Despite the surgery, the cats saw quite well. Myers then placed a patch over one of their eyes and trained the one-eyed creatures to distinguish between a circle and a square, knowing that the information they acquired would go to only one hemisphere. When he switched their eye patches to cover their trained eyes, however, the cats performed just as well as before. Their memory of this skill was intact. This meant either that the knowledge was stored in the central brain stem, well below the twin hemispheres, or that the knowledge acquired by one hemisphere had somehow been transmitted to the other.

"Obviously the *corpus callosum* was the next thing to test," recalls Dr. Myers. "But from the available evidence, cutting it would have no effect. If the surgery is properly done, the animals are up the next day and you see nothing." By all outward appearances, a split-brain cat or monkey is perfectly normal: it can run, eat, mate, solve problems as if nothing had happened to it. When surgeons first split the brain of a human being in the nineteen-thirties (to remove a tumor deep in the brain), they did so with much trepidation, expecting a terrible change in their patient, a total deterioration of his psyche. To their amazement, they saw no change at all. The *corpus callosum* seemed to serve no purpose, despite its large size (it is about 3½ inches long and a quarter of an inch thick in humans). "What is the function of the *corpus callosum*?" professors would ask their students in the nineteen-forties; as no one knew,



Split-brain problem: A patient whose brain has been surgically divided feels the outline of the figure 3 with his left hand, perceiving it with his right half-brain. Knowledge of it is not transferred to his left half-brain, which controls his right hand. Asked to indicate the number he has grasped, he does so incorrectly with his right hand.

Maya Pines is author of "The Brain Changers: Scientists and the New Mind Control." This article is adapted from a chapter of that book, which will be published by Harcourt Brace Jovanovich late next month.

they replied facetiously, "It transmits epileptic seizures from one hemisphere to the other." As recently as 1951, the famed neuropsychologist Karl Lashley saw only one other use for it: "To keep the hemispheres from sagging."

Nevertheless, Myers proceeded with the next step in the research plan. After cutting through the cats' optic chiasms, he split their *corpora callosa* as well, separating their left and right hemispheres. Then he trained them as before, with one eye covered. When he removed the cover from this eye and placed it over the other eye, however, there was a dramatic change: The cats reacted as if they had never seen the patterns before. They took just as long to learn the difference between a circle and a square with the second eye as they had with the first. Myers was elated, and the question was finally settled: It was the *corpus callosum* that transmitted memories and learning from one hemisphere to the other. The thick band of fibers stood revealed as the sole means of communication between the two halves of the cerebral cortex. Without it, cats could be trained quite separately with each eye. When Myers tried teaching some split-brain cats to select the circle with their left eyes and the square with their right, he found that they learned this without the slightest evidence of conflict. They would act in opposite ways, according to which eye was open—as if they had two entirely separate brains.

In animals, a split brain may prove relatively unimportant, for the left and right halves of their brains do exactly the same job. But this is not the case for human beings. Alone among the mammals, man has developed different uses for each half of his brain. This asymmetry, which we all recognize when we say whether we're right- or left-handed, is the glorious mechanism through which man is able to speak. It is what separates us from the apes. There are various theories about how it developed and whether it is present right from birth, but it is quite clear that by the time a child reaches the age of 10, one hemisphere—usually the left—has taken over the task of language.

For simpler operations, such as receiving sensations from one's hand or ordering movements to one's foot, the human brain remains generally symmetrical. The nerve impulses that carry messages from one side of the body travel up the spinal column and cross over into the opposite side of the brain, there to stimulate predetermined cells to form a sort of map of the parts they represent. The nerve connections involved are set at birth in an incredibly precise fashion that allows the brain to know instantly where certain sensations come from and where to aim specific instructions.

When tasks become more complex, however, this fixed plan is abandoned. Then the association areas of the brain come into play, and each one develops in its own way, according to experience. Since we have only one mouth (unlike the dolphin, which has

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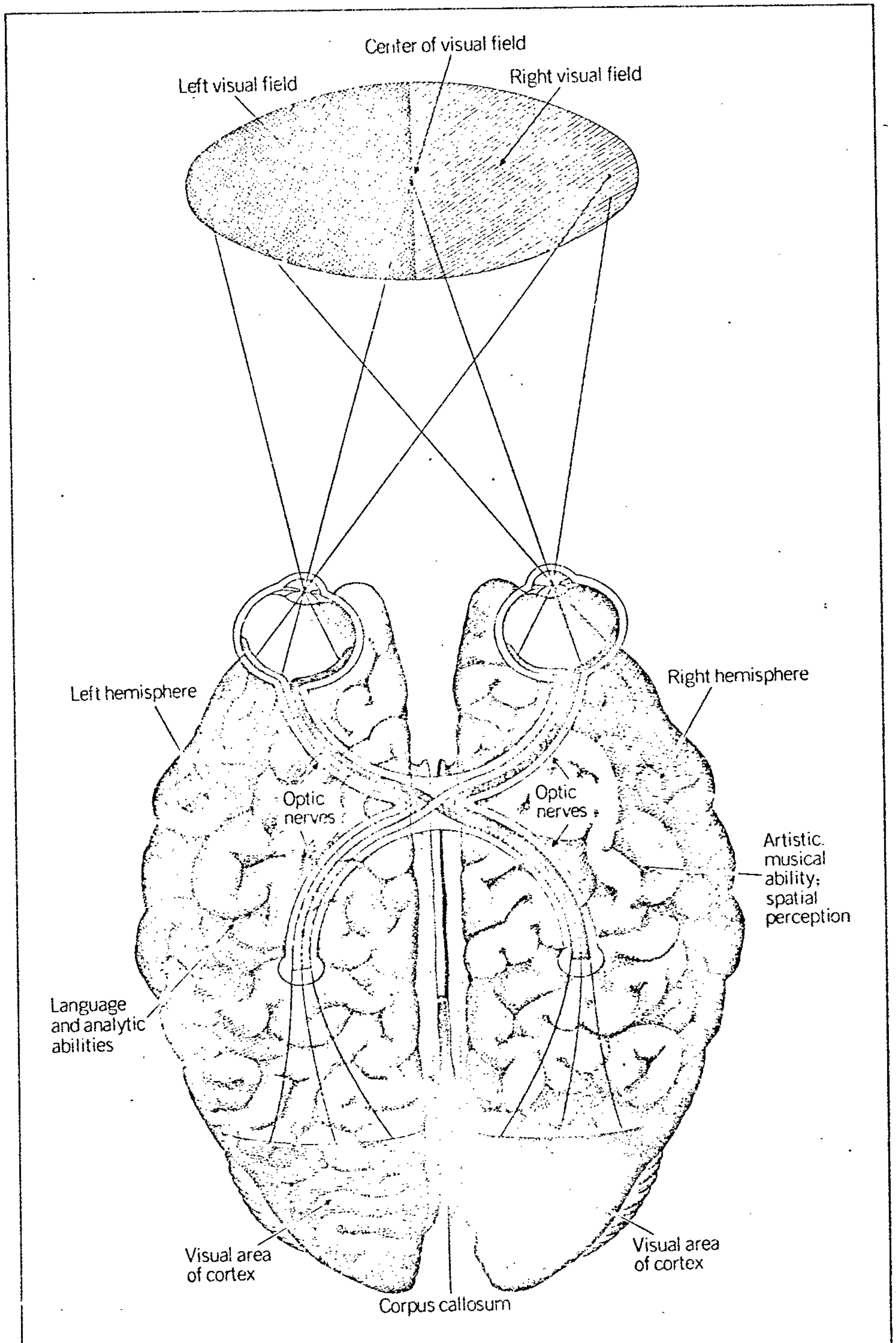

Two views of the world: Objects in the left visual field are perceived in the brain's right hemisphere and objects in the right visual field are perceived in the left. Normally, the corpus callosum is intact and perceptions transfer through it from one hemisphere to the other. When the corpus is cut, as above, perception is divided. For example, one patient with such a split brain found he could read only words that appeared in the right visual field, since literacy is a function of the left hemisphere.

Brain

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separate phonation mechanisms on the right and left sides of its body), there is no need for right and left speech mechanisms. In most adults, therefore, the speech centers are limited to one side of the brain, usually the left, though about 15 per cent of left-handers and perhaps 2 per cent of right-handers have speech on both sides.

Being left-handed—an inherited trait—generally means that the two sides of one's brain have not become as fully specialized as among right-handers. The 10 per cent of the population who are left-handed in childhood tend to be ambidextrous, and according to some recent research by the University of Pennsylvania's Dr. Jerre Levy, they often score much lower on tests of perceptual or motor ability. Furthermore, there are two kinds of left-handers: those whose language is controlled by the right hemisphere (less than half of the total), and those in whom the left hemisphere controls speech, just as in right-handers.

This makes the left side of the brain largely dominant for language in human beings—a near-monopoly that was recognized in the early 18th century, when surgeons examined the brains of people who had lost the power of speech and found severe damage on the left side. Why this should be so preordained is not clear. The left hemisphere tends to become dominant in other ways as well. For example, it controls the right hand, which does most of man's skilled work with tools.

Around the age of 1, notes psychologist Jerome Bruner, babies suddenly master what he calls "the two-handed obstacle box," a simple puzzle developed by Harvard's Center for Cognitive Studies to study how babies learn the value of two-handedness. The baby will learn to push and hold a transparent cover with one hand while the other hand reaches inside the box for a toy, even though nobody has taught him this skill. To Bruner this seems extraordinary, for it shows that the baby has learned to distinguish between two kinds of grip—the power, or "holding," grip, which stabilizes an object, usually with the left hand, and the precision, or "operating," grip, which does the work, usually with the right. Monkeys and apes also develop a precision grip, says Bruner, but only in man, with his asymmetry, does the power grip migrate to the left hand while the precision grip migrates to the right. This ability to specialize is the beginning of a long road leading to the distinctively human use of tools and toolmaking.

If the left hemisphere does all this, why do we need a right hemisphere? Experiments with split-brain cats and monkeys could not shed much light on the differing specialties of man's two hemispheres. The study of the two personalities in our brain did not really begin until 1961, when Sperry became interested in a 48-year-old veteran whose head had been hit by bomb fragments during World War II.

A FEW years after his injury, W. J. had begun to have epileptic fits; these became so frequent and so severe that nothing could control them. He would fall down, unconscious and foaming at the mouth, often hurting himself as he fell. For more than five years, doctors at the White Memorial Medical Center in Los Angeles tried every conceivable remedy, without success. Finally Drs. Philip Vogel and Joseph Bogen cut through his *corpus callosum*, and the seizures stopped, as if by magic. There was a rocky period of recovery, during which W. J., a man of above-average intelligence, could not speak, but within a month he announced that he felt better than he had in years. He appeared unchanged in personality. He seemed perfectly normal.

Meanwhile, Sperry had interested a graduate student, Michael Gazzaniga, in performing a series of tests on W. J., together with him and Dr. Bogen. Gazzaniga soon discovered some extremely odd things about his subject. To begin with, W. J. could carry out verbal commands ("raise your hand," or "bend your knee") only with the right side of his body. He could not respond with his left side. Evidently the right hemisphere, which controls the left limbs, did not understand that kind of language. When W. J. was blindfolded, he couldn't even tell what part of his body was touched, if it happened to be on the left side.

In fact, as the tests proceeded, it became increasingly difficult to think of W. J. as a single person. His left hand kept doing things that his right hand deplored, if it was aware of them at all: Sometimes he would try to pull his pants down with one hand, while pulling them up with the other. Once he threatened his wife with his left hand while his right hand tried to come to his wife's rescue and bring the belligerent hand under control. Gazzaniga, now a professor of psychology at the State University of New York at Stony Brook, recalls that he was playing horseshoes with W. J. in the patient's back yard when W. J. picked up an ax with his left hand. Alarmed, Gazzaniga discreetly left the scene. "It was entirely likely that the more aggressive right hemisphere might be in control," he explains. And since he couldn't communicate with it, he didn't want to be the victim in a test case of "which half-brain does society punish or execute."

Only the left half-brain could speak. The right one remained forever mute, unable to do any tasks that required judgment or interpretation based on language. Of course, it was also unable to read. This meant that whenever he was faced with a page of printed matter, W. J. could read only the words in the right half of his visual field, which projected to his left hemisphere. His right hemisphere seemed blind. Reading thus became very difficult and tiring for him. He also found it impossible to write any words with his left hand, although he had been able to do so with a little effort before his operation. (He was thoroughly right-handed.)

Indeed, from the early tests on W. J. it appeared at first that his right hemisphere was nearly imbecilic. But then came the day when W. J., with a pencil in his left hand, was shown the outline of a Greek cross. Swiftly and surely, he copied it, drawing the entire figure with one continuous line. When he was asked to copy the same cross with his clever right hand, however, he could not do it. He drew a few lines in a disconnected way, as if he could see only one small part of the cross at a time, and was unable to finish the pattern. With six separate strokes, he had made only half of the cross. Urged to do more, he added a few lines but then stopped before completing it and said he was done. It was clearly not a lack of motor control, but a defect in conception—in striking contrast with the quick grasp of his nonverbal half.

SINCE then, a tantalizing picture of the brain's mute hemisphere has begun to emerge. Far from being stupid, the right half-brain is merely speechless and illiterate. It actually perceives, feels and thinks in ways all its own, which in some cases may prove superior. The only problem is to communicate with it nonverbally, as if it were an exceedingly intelligent animal.

There are some revealing movies of the first split-brain patients to be studied in Sperry's lab. (By now, 18 patients have been tested there.) One sequence shows a 12-year-old boy seated before a screen with his eyes fixed on a point in the center of it. When pictures of various objects are flashed to the right or left of this point, each picture is seen only by the opposite hemisphere. A picture is flashed in the boy's left visual field, which is controlled by his right half-brain, and the boy says he saw nothing. (That, of course, is the left hemisphere speaking.) But at the same time his left hand (controlled by his right hemisphere) searches behind the screen, rejecting a wide variety of objects, until it finally finds, by touch, what it is looking for: a pair of scissors, to match the scissors that the right hemisphere saw on the screen.

In other frames, W. J. is seen trying to arrange some colored blocks according to a diagram. He has no trouble at all doing this construction test with his left hand. But when his right hand tries, it gets hopelessly mixed up. Impatiently, his left hand shoots forward to help him, but the experimenter pushes it back. The right hand continues turning the blocks this way and that, achieving nothing. Again the left hand tries to come to the rescue, only to be pushed back. Peeved, W. J. sits on that hand to keep it quiet. But he still can't do the block design with his right hand. When he is told he can try it with both hands, however, the situation grows even worse: the two hands seem to fight for control, with the right hand tearing down whatever the left hand has built.

In spatial abilities, the right hemisphere is clearly tops. It also recognizes faces better than the dominant left, as was shown recently with the aid of some very curious split faces developed by Dr. Colwyn Trevarthen and Dr. Levy in collaboration with Dr. Sperry. They cut several pictures of faces in two, then stuck some unlikely combinations together—the left side of an old man with the right side of a young woman, for instance — and flashed each composite picture briefly on a screen. The split-brain patients who were used as subjects for this experiment kept their eyes fixed on a red dot in the center of the composite, so that the half-face in their left visual field could be projected only to their right hemisphere, and vice versa. After each composite picture had appeared on the screen, the patients were shown a choice of faces and asked to "point to the face you saw." Whether they used their right or left hand, they always pointed to the face matching the half that had been flashed on the left side of the screen, the half that had projected to the right side of their brain. This indicates that recognizing faces is a special ability for which the right hemisphere is dominant, the researchers believe. The left hemisphere never had a chance to select its candidate, since the right hemisphere always made the choice first. (Even in a split-brain patient, the right hemisphere can still control some movements of the right, as well as the left, hand.) When, instead of pointing, the patients were asked to *tell* what they had seen, however, they made the opposite choice and described the half-face on the right, since that was the only thing their verbal side had seen. But they replied strangely, as if in a dream, explaining that they were confused. Sometimes they said, vaguely, that they didn't quite remember. However, they never once complained that there had been anything strange about the picture itself.

In general, the right hemisphere seems better at grasping the total picture, the *Gestalt*, of a scene. And this talent cannot be limited to people whose brains have been split. It must be a form of specialization in all people, resulting from a division of labor much like that which gave language to the left hemisphere.

HOW many other special skills or talents are the province of the right hemisphere? Nobody knows. But many of man's more poetic or imaginative aspects may stem from there. A few years ago, the Russian psychologist A. R. Luria described a composer who became speechless after a stroke, yet went on to compose better music than ever before. He could no longer *write* the notes, but he could play and remember them. Other people who lost the use of their right hemisphere remained able to speak, but could no longer remember melodies. So musical talent, too, appears to be largely located in the right hemisphere.

Nor is the right hemisphere totally wordless, after all. With the exception of W. J., who had had more damage to his brain before his operation, the patients examined in Sperry's lab have usually proved able to understand a few written or spoken words —simple nouns and a few elemental verbs — with their right hemisphere. Some could even add up to 10, as long as this was expressed nonverbally.

There is thus a lot of brainpower in the mute, inarticulate hemisphere. Coupled with this comes a full complement of emotions. One part of the movie made in Sperry's lab shows a young woman beginning to smile in an embarrassed way as the picture of a nude is flashed in her left visual field. When she is asked what was on the screen, however, the young woman replies that she saw nothing. Again the nude is flashed on the left side of the screen. This time the young woman blushes. A slow grin spreads across her face, and she even hides her face in embarrassment. But when asked what she saw, she again insists that there was nothing there. Pressed to explain why she was laughing, all she can say is, "Oh, that funny machine!"

Just as the right hemisphere can make the whole face laugh (though the left hemisphere does not know why), it can make it express displeasure, even after the *corpus callosum* has been cut. "This is evidenced in frowning, wincing, negative headshaking and the like, in test situations where the minor hemisphere hears the major making stupid verbal mistakes—in other words, where the correct answer is known only to the minor hemisphere," notes Sperry. "The minor hemisphere seems in such situations to be definitely annoyed by the erroneous vocal response of its better half." At such times, though, the verbal half-brain would be unable to tell why the face to which it is attached frowned or winced, or why the head shook.

All these abilities point to the presence, in the right hemisphere, of "a second, separate, conscious system that is definitely human in nature," as Sperry puts it. Nevertheless, the dominant hemisphere clearly does not trust its twin, at least in split-brain patients, and generally prefers to ignore it, if not put it down. The left hemisphere will usually deny that the left hand can do anything like retrieving, out of a grab bag, some object previously felt by that hand. When asked to do this for the first time, Sperry's subjects generally complain that they cannot "work with that hand," that the hand is "numb," or that they "just can't feel anything" or "can't do anything with it." If the left hand then proceeds to do the job correctly, and this is pointed out to the patient, the speaking half will reply, "Well, I was just guessing," or, "Well, I must have done it unconsciously." It never even acknowledges the existence of its twin.

Much mystery surrounds the behavior of the two half-brains in normal people. Nobody knows whether these twin halves also ignore each other, actively inhibit each other, cooperate, compete or take turns at the controls. Sperry believes that they mostly cooperate, because of the 200 million fibers connecting them. But there are other opinions.

The best clues come from children and adults who have had terrible accidents. If a child's left hemisphere is destroyed by a head injury or tumor before he is 5 or maybe even 10 years old, he can learn to speak again—sometimes after a year of silence. His right half-brain will slowly take over the job. Not so for adults, who regain some speech after a stroke only if they have enough uninjured tissue remaining near the injury, on the left side. They cannot use their right half-brain for speaking. If a young child is injured in the right hemisphere, however, he will also experience difficulty with speech, though an adult would not.

"The young child has speech and language on both sides of his head," Gazzaniga believes. "He is, to some extent, a split brain, whose hemispheres tend to develop independently and duplicate each other." At birth, the *corpus callosum* is only partly developed. It isn't until a child is about 2 years old that the link between his two hemispheres becomes really functional, so that everything experienced by one side is instantly available to the other. At that point, duplication of learning becomes less frequent, and true specialization begins.

By the age of 10, dominance for speech—and probably for other skills as well—is fixed. Tasks of synthesis, spatial perception and music apparently go to the right side. The left side gets all the sequential, verbal, analytical, computerlike activities. And, strangely, "excellence in one tends to interfere with top-level performance in the other," Sperry notes. To avoid bottlenecks, eventually most of the traffic flows in one direction, while few opportunities arise for the other hemisphere to develop its own skills. The "traffic cop" in this case may well be the *corpus callosum*. The speech learned by the right hemisphere in early childhood is thus functionally suppressed. In time, it may be lost or perhaps erased.

In California recently, two young psychologists have been studying how normal people use or suppress their hemispheres. When you write a letter, for instance, does the left side of your brain show more electrical activity than the right? By pasting electrodes on the scalp of volunteers, Drs. Robert Ornstein and David Galin of the Langley Porter Neuropsychiatric Institute, in San Francisco, have found that this is indeed the case, at least in right-handed people. The left side of their brains produced the characteristic fast waves of attention or activity, while the right side relaxed with slow, high-amplitude waves, including the alpha rhythm. When the volunteers were asked simply to *think* about writing a letter, thus eliminating the effect of muscle movements, the pattern was exactly the same. Their right half-brain again relaxed, idle, and their left half showed fast waves. A similar pattern appeared when they read a column of print, did mental arithmetic, made up a list of verbs beginning with the letter "R," and completed sentences. But exactly the reverse happened when they tried to reproduce designs with four-colored blocks, remember musical tones or draw with an Etch-a-Sketch: This time, the left side of the brain had more alpha rhythms, as if it were turned off, while the right side showed fast waves.

"Our opinion is that in most ordinary activities, we simply alternate between cognitive modes, rather than integrating them," declare Ornstein and Galin. "These modes complement each other but do not readily substitute for each other." Thus, when people are asked to describe a spiral staircase, they may begin by using words, but soon switch to hand gestures.

Ideally we should be able to turn on the appropriate hemisphere and turn off the other, whenever the task requires it. But in fact we cannot always do it. "Many persons are dominated by one mode or the other," observes Dr. Ornstein. "They either have difficulty in dealing with crafts and body movements, or difficulty with language." Culture apparently has a lot to do with this. Children from poor black neighborhoods generally learn to use their right hemisphere more than the left—they outscore whites on tests of pattern recognition from incomplete figures, for instance, but tend to do badly at verbal tasks. Other children, who have learned to verbalize everything, find this approach a hindrance when it comes to copying a tennis serve or learning a dance step. Analyzing these movements verbally just slows them down and interferes with direct learning through the right hemisphere.

"We don't have the flexibility we could have," says Ornstein. "We are under the illusion of having more control than we really do." Early in life, it seems, many of us become shaped either as "left-hemisphere types," who function in a largely verbal world, or as "right-hemisphere types," who rely more on nonverbal means of expression. These are two basically different approaches to the world.

So fundamental are these differences that they influence even the direction in which our eyes turn when we think. This was discovered by Dr. Merle Day, of the V.A. hospital in Downey, Ill., but I learned it from Dr. Ernest Hilgard, of Stanford University, while talking to him about his work on hypnosis. Dr. Hilgard suddenly stared at me, leaning close to my eyes, and said, "Count the number of letters in Minnesota." I did so, avoiding his gaze to concentrate better. "You looked to the right," announced Dr. Hilgard when I finished. This meant that my left hemisphere was more easily activated than my right, he explained. Since electrical stimulation in the right side of the brain makes both eyes veer to the left, and vice versa, looking to the right while thinking showed that the left hemisphere was preferred. However, it also meant that I was not very hypnotizable, since various experiments have shown the right hemisphere to be more amenable to hypnosis. People who look to the left tend to prefer nonverbal tasks, to favor their right hemisphere, and to be easily hypnotized. An unusually large proportion of those who look to the right, as I did, turn out to be scientists, researchers, writers or others who spend much of their time at analytic tasks.

When the habit of always using the same side of the brain becomes too pronounced, it can narrow one's personality, Drs. Ornstein and Galin believe. The two researchers are currently working on a test that may enable them to tell which half-brain a person chronically favors, and whether this habit interferes with the ability to shift dominance to the other side when necessary. They plan to try it out on people who are really specialized, like Ralph Nader (a left-hemisphere type who has no hobbies of any kind) and right-hemisphere potters, dancers and sculptors ("preferably people who have trouble with language"). They expect to find significant differences between the two groups. This should give them a tool with which to guide children or adults to new aspects of themselves, to open them to a full range of experiences.

EVENTUALLY, they hope people will learn to activate the left or right hemisphere voluntarily. This has already been tried in their lab. With electrodes on their scalp to record changes in their brains' electrical activity, and earphones to inform them instantly of how they are doing, half a dozen volunteers have attempted to increase the asymmetry between their two half-brains. So far the results appear promising: Nearly all of the volunteers have managed to activate one hemisphere more than the other, through feedback. They have produced as much difference between their two hemispheres in this way as when actually concentrating on mental arithmetic or drawing. One subject produced even more asymmetry through biofeedback than through a change of tasks.

Some training of this kind may prove particularly useful for children who suffer from what is generally called dyslexia, or specific learning disabilities—a variety of subtle perceptual difficulties that interfere with reading, writing or spelling. About 10 per cent of the nation's children cannot process the information received from their eyes or ears with sufficient accuracy. Despite normal vision and hearing, and normal or even superior intelligence, they may confuse left and right or up and down, or give other evidence of poor coordination. Their symptoms have baffled doctors for years. At a National Academy of Sciences conference in 1969, Dr. Sperry suggested that their problem may be "an overly strong, or extensive, perhaps bilateral, development of the verbal, major-hemisphere type of organization that tends to interfere with an adequate development of spatial gnosis [knowledge] in the minor hemisphere." If there is verbal development on both sides of the brain, the right hemisphere's special skills cannot fully emerge. At the same time the dual verbal systems may compete for dominance in reading or writing, leading to what Gazzaniga calls a problem in decision-making—"Like a husband and wife trying to decide what to have for breakfast; one of them's got to take the lead." If these children don't have a well-established decision system, and then receive two different interpretations of the world, they may be confused or slowed down. Through practice, they might learn to rely on one hemisphere more than the other, thus straightening out their lines of command.

All these attempts at making better use of the hemispheres' specialties pale before the urgency of aiding people who have lost one half of their brain through a stroke. The most pathetic of these patients are those who

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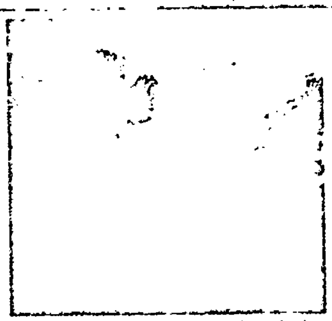
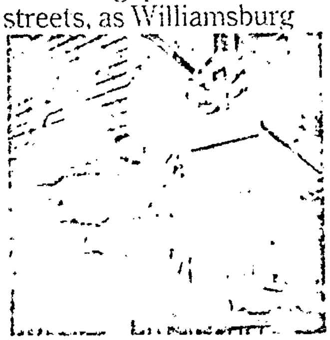
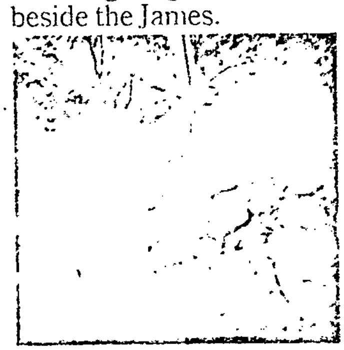
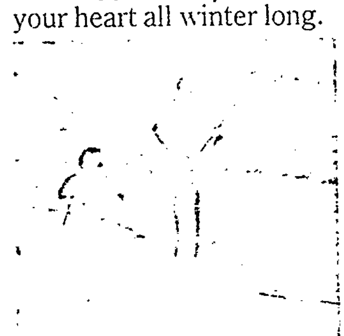
Split-brain pioneer

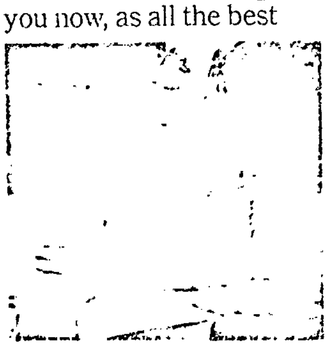
Dr. Roger Sperry observes a split-brain patient on videotape in his Cal Tech laboratory.











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strain to speak, write, express themselves, but cannot, because the left side of their brain has been damaged by a blocked blood vessel. With only their right hemisphere available, they are speechless. Yet there is some preliminary evidence that they may be trained to communicate again, in a rudimentary way.

Surely the right hemisphere of a human brain is cleverer than the whole brain of a chimpanzee, Gazzaniga reasoned. And if chimpanzees can be taught to converse through sign language or plastic symbols, as they appear to have been recently, why couldn't stroke victims learn to communicate as well?

Fired up with enthusiasm after a visit to Santa Barbara, where Dr. David Premack had taught a chimp to communicate by means of plastic symbols, Gazzaniga suggested to a graduate student, Andrea Velletri Glass, that she start reading up on aphasia (the inability to speak) and prepare for a great project. For the next two years, Mrs. Glass worked with a series of speechless patients at N.Y.U.'s Institute of Rehabilitation Medicine, half an hour a day, five days a week. Her first patient was an 84-year-old woman who could neither speak nor understand speech, but who could see that Mrs. Glass was young and smiling at her. She responded, smiling feebly back. Mrs. Glass then showed her some kitchen objects: two identical pots, for instance, and a spoon. She indicated that she wanted the woman to pick out the two objects that were alike, and she repeated the procedure with two forks and a knife, and two bananas and an orange. Her patient understood very rapidly. (With chimpanzees, teaching the concepts "same" and "different" is a long and tedious business.) Then came the first "word"—a green, doughnut-shaped cutout that Mrs. Glass had made out of construction paper. Laying out the two identical pots on a table, she placed the cutout between them. With her mobile, expressive face, she urged her patient to do the same. It did not take the old woman long to figure out that she should insert the cutout between all objects that were the same. She did so, with her good left hand. Her reward: a big smile and expressions of joy on Mrs. Glass's face. Next she learned the word "different"—a hexagon made of orange paper. Within two months, she had a vocabulary of some 12 symbols that she could pick out and place in the appropriate order to make simple statements, such as "Andrea pours water." She knew nouns, negatives and a question mark, but verbs were extremely difficult.

"We've had 12 patients so far," says Gazzaniga, "and it works! That is, it works if they are still bright-eyed. If they are emotionally flat, if they don't want your smile, why should they arrange those shapes to please you?" And the success of the procedure also depends on whether the patient's memory is still good — some were approaching senility at the time of their strokes.

Dr. Premack's chimpanzees have learned much more language than these patients, but only after highly intensive lessons (several hours a day for two years) rather than short lessons for two months. This raises the possibility that the stroke victims, too, could develop a working

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Solutions to Last Week's Puzzles

AMSEL GREENE: PULLET SURPRISES — From *monochrome* and *polychrome*, words within his experience, a pupil rightly assumed that *chrom* means color. Subsequently, however, he concluded that the unfamiliar phrase "chromatic scales" must mean "the kind that rainbow trout have."

S	L	U	E	R		R	A	H	S		D	A	D	S		S	I	S	A	L
L	I	N	N	E		A	S	E	A		D	U	E	L		I	N	T	R	A
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V	E	L	O	C	I	P	E	D	E			S	A	N	E		E	R	O	S
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P	A	T	E	N	T		T	E	N	U	R	E			T	A	U			
A	B	E		D	U	R	A			R	I	S	E	R		T	R	I	P	S
P	O	R	K		S	E	N	S	A	T	E		M	O	T	H	B	A	L	L
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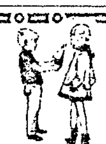

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vocabulary with which to express their basic needs and feelings. Unfortunately, Mrs. Glass had to stop her lessons after a short time as each patient was dismissed from the hospital and sent to a nursing home in another part of the country. The 84-year-old woman, for instance, went off to Florida, and Mrs. Glass herself has moved to Pittsburgh. But eventually she hopes to expand this kind of program to incorporate the whole nursing staff in a hospital, the family and, if necessary, the nursing homes where her patients will live. "Half an hour a day is all right for experimental purposes," she says, "but to really help the patients, they should be encouraged to use the system 12 hours a day." The symbols could then be made of Velcro, which sticks to a Velcro board at any angle, and the word each symbol represents could be printed on it for the benefit of all the literate people who wish to communicate with the patient.

We can experience many things outside of the normal language system, as do young children before they learn to speak. Gazzaniga recently tested two patients at the Cornell Medical School who were being examined for brain tumors. They were about to undergo angiograms — X-rays of their brains' blood vessels, made visible with a special dye. While a needle was in place in their left carotid artery, in the neck, to prepare them for the injection of dye, small doses of Amytal (an anesthetic) were injected into their left hemisphere, putting it briefly to sleep — a method used in many studies of brain function. His purpose was to show exactly which side their speech center was on.

"It's a very dramatic procedure," reports Gazzaniga. "The patient lies on a table, with both hands held in the air. Twenty seconds after the drug goes in, his right hand sinks down—he's completely paralyzed on the right side, though the other side of his brain remains awake, for a minute and a half. This is our testing time. We put an object, say a cigarette, in his left hand. He feels it. His right hemisphere, which controls that hand, is wide-awake. We remove the cigarette. Then the effects of the Amytal wear off and the left hemisphere wakes up. We ask the patient how he feels. 'Fine,' he replies. 'What did I put in your hand?' I ask. 'I don't know,' says the patient. 'Are you sure?' 'Yes,' he says. Then we show him a series of objects—a pencil, a pad of paper, a comb, a cigarette—and ask him, 'Which one was it?' In spite of everything he has said, his left hand immediately points to the cigarette."

This shows that the memory trace, or engram, of the cigarette was encoded in his right hemisphere, and that it could be expressed nonverbally, but that the verbal side of his brain did not have access to it.

"It's a psychiatrist's dream," Gazzaniga says. "Something that's there, in the patient's brain, and that influences his behavior, but that he can't get at!" It may explain why memories formed in earliest childhood are inaccessible, he notes. The memories may be sharp and clear. They may control future behavior. But since they were formed before the child learned to speak, they cannot be recalled through the language system, not even through what the Russian psychologist Lev Vygotsky called "inner speech," speech for oneself, or thought.

Vygotsky believed that thought is born through words. Without words, he said, quoting a Russian poet, "My thought, unembodied, returns to the realm of shadows." Our earliest memories, too, dwell in a realm of shadows. And yet, something was experienced, and something of its flavor remains to haunt us through the rest of our lives.

Perhaps the right hemisphere's functions are too shrouded in shadows to be called thought. According to the Australian physiologist Sir John Eccles, a Nobel Prize winner, the right hemisphere

Experiment: A baby given a transparent plastic box reveals his knowledge of two-handedness—one to hold the lid, the other to grasp the contents—a reflection of left- and right-brain functions.

Conflict

A split-brain patient threatens an aggressive act with his left arm (controlled by his right half-brain) while his right arm (controlled by his left half-brain) moves to restrain it.

cannot truly think. He makes a clear distinction between consciousness of sounds or smells, which we share with animals, and the world of language, thought and culture, which is man-made. Animals can be conditioned, but they cannot create a culture, he claims. Primates leave no constructions, no art, nothing that can live beyond their own time, despite a brain almost as large as man's. In his opinion, everything that is truly human derives from the left hemisphere, where the speech center is, and where interactions between brain and mind occur. When the right hemisphere of a woman whose brain has been split sees something that makes her smile or blush, it's not correct to say she can't report why she smiled—she doesn't *know* why she smiled. Only the left hemisphere can have true thoughts or true knowledge, through language.

"Could the right half of the brain appreciate Chaplin's silent movies?" Eccles was asked at a meeting of the Society for Neuroscience recently. "How would you know?" he shot back, to much laughter in the audience. Both the report of such appreciation and our understanding of it would require the left hemisphere.

Nevertheless, the evidence increasingly favors a generous view of the right half-brain, whose role may be far more important than we know today. When Einstein was asked how he arrived at some of his most original ideas, he explained that he rarely thought in words at all. "A thought comes, and I may try to express it in words afterwards," he said. His concepts first appeared through "physical entities" — certain signs and more or less clear images that he could reproduce and combine. These elements were "of visual and some of muscular type," he added. "Conventional words or other signs have to be sought for laboriously only in a secondary stage, when the mentioned associative play is sufficiently established and can be reproduced at will." This held true only for his creative work in physics; in other activities, he had no trouble with words. He liked to compose limericks, and his letters were both fluent and pithy. Apparently he could make exceptionally good use of both sides of his brain. However, his love of music and his reliance on nonverbal concepts seem to indicate a preference for his right hemisphere.

For centuries we have concentrated on the verbal side of our brains: the side that produces things we know how to analyze and measure. Our mute half-brain remains uncharted. We know almost nothing about how the right hemisphere thinks, or how it might be educated—and we have just begun to discover how much it contributes to the complex, creative acts of man. ■