THE SPLIT BRAIN LAB

by WAYNE SAGE

While some researchers study human behavior for the meaning of consciousness and a dual mind, neurobiologist Roger Sperry continues his careful scientific scrutiny of the physiology of the human brain.

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The suspicion that we each have not just one mind, but two, has been around for a long time. The mind with which we communicate with the outside world as we reason our way along fails all too often to convincingly explain our behavior. If, as Freud insisted, a second consciousness influences what we do and say in ways our conscious minds can only try to rationalize, those who tried to probe that subliminal second psyche generally ended up beguiled by the vagaries of human nature. Psychology, determined to be a science, turned to mindless behaviorism.

But a new mentalism may be upon us. This time the theories of dual consciousness are not borne of conjecture and inference, but of laboratory experiments that seem to make the conclusions logically inescapable.

For more than 20 years, neurobiologist Roger W. Sperry, Ph.D., of the California Institute of Technology in Pasadena and his colleagues, most notably J. E. Bogen, now at Ross-Loos Medical Group in Los Angeles, and Michael Gazzaniga at the University of California, Santa Barbara, have sought the psyche not in their subjects' ramblings, but in the physiology of their brains. They seem to have discovered in each subject two distinctly different consciousnesses, worlds of perception and thought that are more than the neurological circuits through which they channel. Says Dr. Sperry: "The term 'mental forces' would seem to be appropriate."

The grand guru of the theories themselves is psychologist Robert Ornstein, whose book *The Psychology of Consciousness* split not only the mind, but the cultures of the world in his double-barreled view of mentality. The left hemisphere of the brain, concludes Ornstein on the basis of Sperry's findings, operates rationally; it dominates the mental way of the Western world. The right hemisphere works intuitively and is the consciousness of the East. From such groundwork, Ornstein points to everything from peyote to yoga to the symbolism of Walt Disney cartoons as manifestations of such divergent mentalities.

The objective evidence from which Ornstein expounds is Sperry's demonstration that the two hemispheres of the cerebrum are basically different in the way they think and relate to the world outside the human skull. As the left brain to Ornstein's right brain, Sperry was intrigued by the fact that each of the hemispheres of the cerebrum—the centers of higher intellect that sprout like two giant cauliflowers from the more primitive areas of the brain—have always seemed oblivious to each other's existence. Patients could lose virtually the entire right hemisphere through injury or surgery, it was found, and be unaware that it was gone until it was demonstrated for them through laboratory tests that parts of their visual field were missing. Also, experiments with animals, in which the nerves connecting the two hemispheres were split, showed that each side of the brain learned independently and had a separate memory. A task or response taught to the left hemisphere, which normally controls the right hand or paw, had to be retaught to the right hemisphere, which performed the same task with the left hand or paw. Even more intriguingly, one side of the brain could be put to work on one task while the other side of the brain was being trained simultaneously to do something else.

The full significance of such separation became evident only within the last 12 years, when the opportunity arose to study the hemispheres separately in humans. That opportunity was made possible by Los Angeles Drs. Phillip J. Vogel, chief of neurosurgery at the White Memorial Medical Center, and Bogen at Ross-Loos Medical Group, who surgically severed all nerves connecting the left and right hemispheres of the cerebrums of 16 patients. Those patients provided the only chance to study separately the two lobes of the human brain.

All the patients were intractable epileptics. The surgeons were trying to isolate seizures so they would not transfer from one side of the brain to the other. While a seizure was going on in one side of the brain, they hoped the other side would take over control of the body. It worked, and the patients continued their lives with no apparent repercussions from the surgery.

How such radical surgery could leave patients apparently unaffected became known through Sperry's experiments with them. Investigating the apparent indifference of the two hemispheres to the fact that all communication had been cut off between them, Sperry colleagues Jerre Levy and Colwyn Trevarthen constructed a set of "chimeric stimuli." They gathered a set of photographs of different faces—a beautiful young female fashion model, a pudgy-cheeked boy, an old codger and so on—and cut each photo down the middle of the face. The halves of two different faces were pasted together, and the reconstructed photos were then covered and mounted precisely at the midpoint of the subject's visual field so that the left side of the photo would be visible only to that part of the retina relaying information to the right hemisphere of the brain. The right half of the picture (which was half a photo from a different face) would appear in the visual field of the brain's

Illustrations by Michael Steirnagle

left hemisphere. With the subject's head held still, the image was then flashed before his or her eyes at one-tenth of a second—too fast for the eyes to jerk to examine the opposite visual fields.

The result was the discovery of two completely separate visual worlds within the same head. When the subjects were asked what they had seen, the response was the name of the old man in the right half of the photograph when half old man and half young man was shown. But when asked to point with their left hand to the complete photo of the person they had seen, the left hand pointed to the photo of the young boy. With the subjects saying they had seen one photo but with their left hand pointing to another photo, the experimenters asked the subjects if they had noticed anything unusual about the picture that had been flashed before them. They said no, nothing at all. Clearly, each side of the brain had seen half a face, filled it in (as experiments in perception have shown the mind is wont to do), and neither side was aware of what the other had seen.

Further experiments were conducted with other types of images. In one such trial, the phrase *key ring* was shown to the subjects, again set at the midpoint of the visual field so that the first word, *key*, went into the right hemisphere while the latter, *ring*, was relayed to the left hemisphere. When asked to read the word they had seen, the subjects said "ring." When asked to retrieve the object with their left hand from a group of objects on the table, the subjects picked up the key—without realizing any contradiction in what they were doing.

"Each hemisphere has its own inner visual world, each cut off from the conscious awareness of the other," wrote Sperry following the investigations. But the full significance of that finding was just dawning. Later, after further experiments, he would add: "Each of the separated hemispheres appears to have its own private sensations, perceptions, thoughts, feelings and memories. Everything we have seen so far indicates that the surgery has left each of these people with two separate minds, that is, with two separate spheres of consciousness."

With the subjects straddled across their visual fields, each arm extended behind a partition and their eyes fixed forward, all visual input was channeled separately to the left and right hemispheres. Each side of the brain was presented with a puzzle of geometric forms. The experimenters stood back and watched in amazement as each hand went about trying to figure out the puzzle on its own, each approaching the problem in its own way, the left hand literally not knowing what the right hand was doing.

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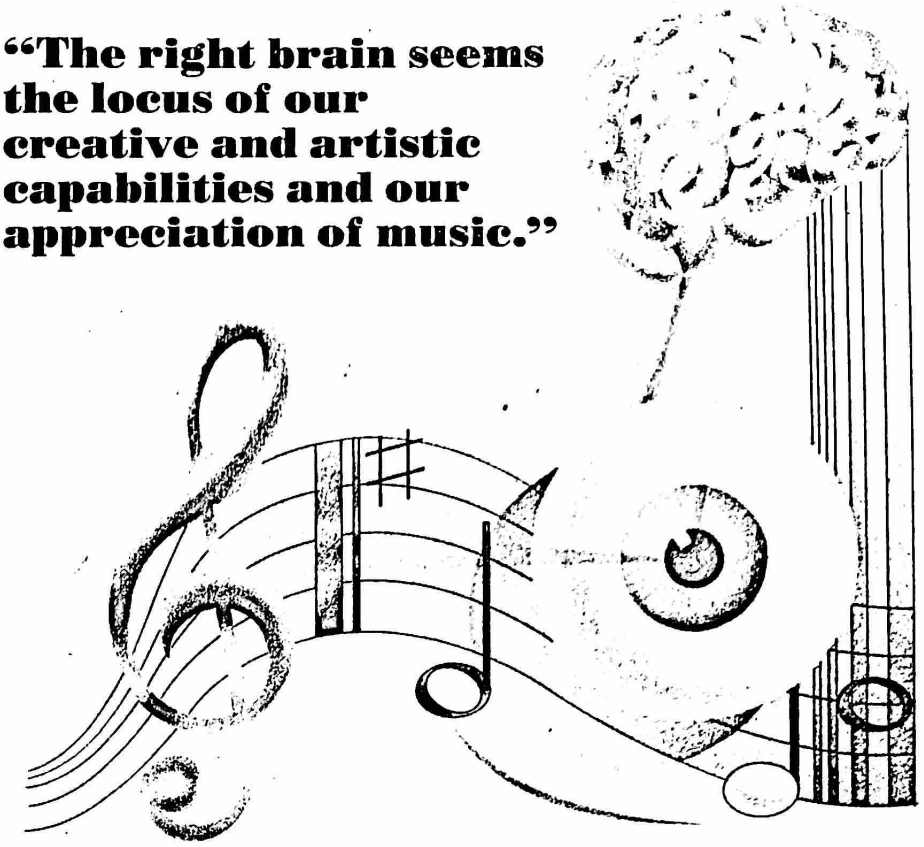


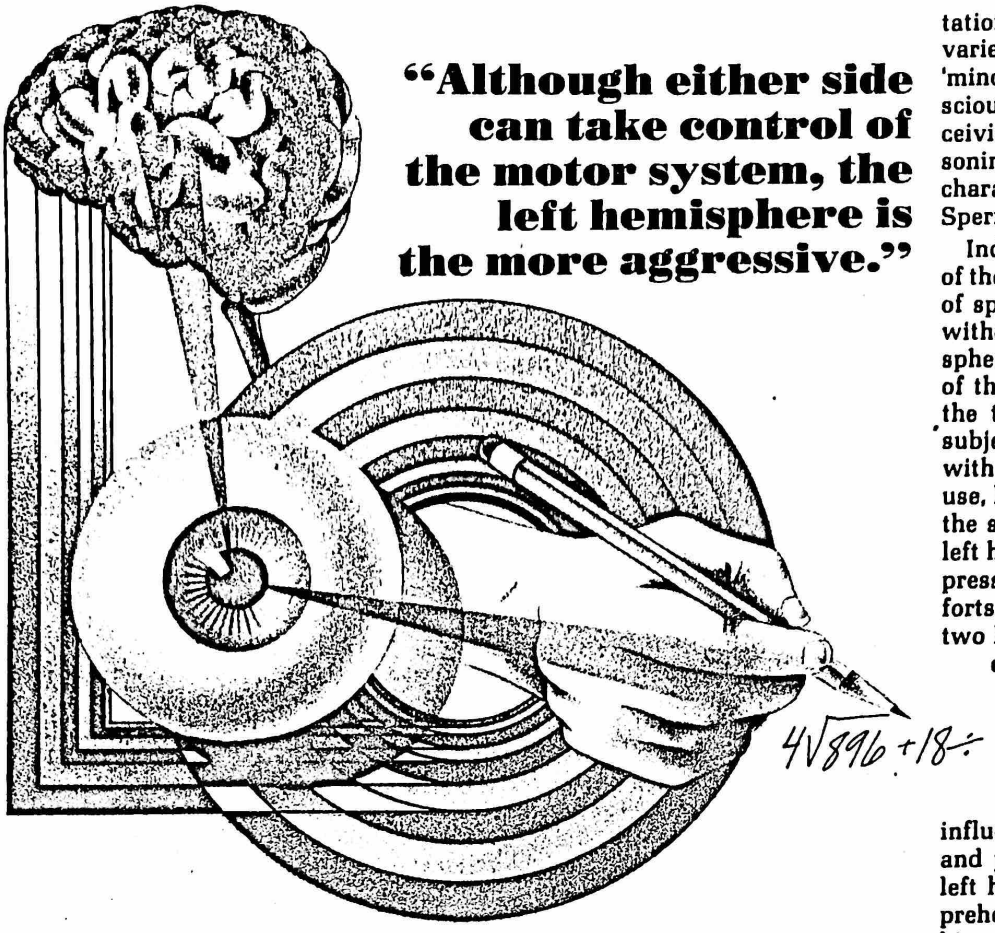
The left hemisphere, using the right hand, seemed to approach the task in a logical manner, examining edges, murmuring to itself about similarities and differences and how the forms might fit together. The right hemisphere, using the left hand, seemed to take a totally intuitive approach, trying various spatial arrangements and, interestingly, generally solving the puzzles much more quickly than did the reasoning left hemisphere.

This difference in the way the two hemispheres of the brain think would revolutionize the psychology of consciousness. As the experiments progressed, the left brain, as the left hemisphere of the cerebrum came to be called, was found consistently to be our rational lobe. It takes in information bit by bit, processes it in linear, logical fashion and carries on verbal and mathematical reasoning. It is verbal and uses language to communicate with the outside world. The right hemisphere never speaks. It perceives images holistically in gestalts. It thinks abstractly, processes information in a spatial and intuitive way and seems to be the locus of our creative and artistic capabilities and our appreciation of forms and music.

The question as to why such doubling in visual perception should take place also seemed to make sense at last. All visual input was being seen separately by each side of the brain because each hemisphere was making quite different use of it.

How two completely separate consciousnesses could coexist may seem almost incomprehensible, at least to the left hemisphere reading this article. But such oblivion is maintained throughout our lives. Each lobe of the brain sees the world through the same eyes, hears through the same ears and, generally by virtue of living in the same body, has the same experiences as they develop. The left brain talks, rationalizes and reasons its way through life; the right rides along silently absorbed in its own mental world, contemplating it in its own nonverbal way.

"The brain is oblivious to what it lacks," explains Sperry. "Neither hemisphere knows about the experiences of the other; one hemisphere remains oblivious to the existence of the other. It's what you lose when you have a deep



"Although either side can take control of the motor system, the left hemisphere is the more aggressive."

sleep without dreams," he adds, explaining the lack of awareness of brain-damaged patients who lose their right hemisphere and do not know it's gone.

One expert in dream research has suggested that the hemispheres may dream separately as well. This may explain the prevalence of strangers in our dreams. Over 40 percent of the characters in dreams are people who subjects say they have never seen before, research has shown. They may be people the right hemisphere has seen, but whom the left hemisphere does not remember because they have no verbal label. Research under Sperry has shown that the right hemisphere easily associates names with faces, but the left hemisphere has difficulty doing this. Also, researchers probing the REM (dream) stages of sleep often dredge up verbal content that does not correspond to the images. This may happen when the left hemisphere goes off dreaming verbally on its own, paying no attention to the images dreamed up in the brain's right lobe.

Unlike the brains of Sperry's subjects after surgery, the hemispheres of our brains do normally engage in a sort of cross talk. But just how they communicate and cooperate and in what terms is only dimly understood. Although either hemisphere can take control of the motor system, the left hemisphere—that consciousness we usually see in action and communicate with in others—is the more aggressive, executive (and some have said "masculine") hemisphere in running the body. Traditionally, it was called the "major hemisphere." Some experts were reluctant to believe the "minor hemisphere" on the right was even conscious, because they could not communicate with it.

"The reasoning seemed to be that the conscious self by nature has to be single and unified, as if the gates of heaven shall be opened only to one psyche per cranium," says Sperry. "The mute minor hemisphere seems to be carried along much as a passive, silent passenger who leaves the driving of behavior mainly to the left hemisphere . . . lacking language like the animal brain and unable to communicate what it is thinking or experiencing. It is much less accessible to investigation, and accordingly the nature and quality of its inner mental life . . . have remained relatively obscure."

Sperry's experiments seemed to demonstrate that the right hemisphere is not only conscious but, indeed, may be vastly underestimated in its capability and influence. "It is our interpretation, based on a large number and variety of nonverbal tests, that the 'minor hemisphere' is indeed a conscious system in its own right, perceiving, thinking, remembering, reasoning, willing and emoting, all at a characteristically human level," says Sperry.

Indeed, when the "minor hemisphere" of the lowest-scoring patient on the test of spatial forms was allowed to work without interference from the left hemisphere, it scored better than 31 percent of the college sophomores with whom the test was standardized. When the subject was presented the same test with free vision and unrestricted hand use, he scored lower than 99 percent of the same group, apparently due to the left hemisphere's interference and suppression of the right hemisphere's efforts. In laboratory tests in which the two hemispheres are in equal and free competition, it was found that either hemisphere was capable of capturing and controlling the motor system.

Perhaps more importantly, the silent right hemisphere may influence what we do and say on subtle and primitive levels, and in ways the left hemisphere does not always comprehend. In one experiment, Sperry and his colleagues flashed a series of photographs before the visual field of the right hemisphere. Among the usual dull laboratory photos were planted arousal photos, such as a picture of a nude body. The instant such a photo flashed by, a female subject became disturbed. She blushed. While the left hemisphere's words denied that anything had happened, her tone of voice made it obvious that this was not the case.

"Emotion is a pretty primitive basic system that has a lot of organization throughout the brain system," explains Sperry. When an emotion is triggered in one hemisphere, the other hemisphere very quickly realizes something is wrong in the body; but in this case, the left hemisphere had not seen the photo and could not explain why it was feeling so disturbed and aroused.

Even with the direct lines of communication cut, extreme care must be taken to keep the two hemispheres from finding other ways to communicate with each other, often in the most subtle ways. For example, the right hemisphere was able to perform well in tasks involving the construction of three-dimensional forms from two-dimensional drawings. When the left hemisphere attempted the task, it fumbled about with the right hand trying to reason its way through and finally gave

up. The right hemisphere, as if unable to restrain itself in the face of incompetence, reached over with the left hand and tried to take over.

In another instance, the left hemisphere was asked to try to figure out which light in a system of colored lights had just flashed. Since the lights were set to come on solely within the visual field of the right hemisphere, only the right hemisphere had seen the flash and knew the answer. Yet gradually, the left hemisphere was able to start coming up with the correct response. Since the right side cannot speak, when it heard the left hemisphere make a wrong guess, it would shake the person's head to let the left hemisphere know it had made the wrong choice. On the next guess, the left hemisphere would give the correct answer, unaware that it had been helped out by the right hemisphere. The researchers thus discovered that the right hemisphere was listening in.

Considerable confusion can also occur. If one hemisphere sees or hears the other give an answer it considers erroneous, it may make the person grimace or frown; or if it is the verbal hemisphere, it may make remarks such as, "What made me do that?" Sperry says, "We purposely do not dwell on these conflicts and pass along to the next trial.

"When one hemisphere takes command of the motor system of the brain stem or cord, it tends to prevent the other hemisphere from getting into that system. We sometimes deliberately put the right hand to a task, like doing a tic-tac-toe or sketching or rolling balls, just to keep it out of the picture so we can get to the right hemisphere."

The most important recent development in efforts to establish and maintain communication with only one hemisphere at a time is the "Z lens," invented by Dr. Eran Zaidel, a young biologist working with Sperry at Cal Tech. The equipment consists of a series of lenses, a prism, a mirror and a screen arranged in an ingenious optical system that focuses light only on that part of the retina that relays information to the left or right hemisphere. The apparatus includes a special contact lens that moves with the eye. With the Z lens, experiments are no longer limited to work with information flashed to one hemisphere during a tenth-of-a-second interval. The system can be set up so that the right hemisphere, for example, can scan a picture or printed page, examine objects before it and otherwise look out at the world on its own for as long as it pleases. The lens has made

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possible a series of tests carried out by Zaidel and Sperry that have even further elucidated the nature of the mysterious and silent right hemisphere.

The prevalent theory on the matter holds that the two hemispheres of the brain develop at an equal rate albeit along separate paths and are equipotential in all functions until around age five, when the hemispheres lose their ability to act interchangeably, each moving into its own specialty, apparently in response to genetic programming due to evolutionary advantage.

Indeed, that seems to be the case, but the theory may seriously underestimate the right hemisphere's ability to figure out such things when called upon to do so. Using the Z lens, Zaidel and Sperry were able to administer standard language tests three times to each subject—once to each hemisphere and then again to both hemispheres together. Despite the fact that the persons tested were considerably different in intelligence, when their right hemisphere was given tests of syntax, in each case it performed at the level of a five-year-old, apparently using what abilities it had developed in such areas before it turned to other matters. Yet its vocabulary was found to be much greater than expected, roughly that of a 14-year-old. It could read single words and very simple sentences and could even read a simple instruction and respond to it in writing.

For example, at one point, a subject was asked in writing to write his name and address.

"Do what it says," Zaidel told him.

The right-handed subject picked up a pencil with his left hand and laboriously wrote his name. When verbally asked what he had done, he replied (that is, his verbal left hemisphere replied), "I have no idea." Yet when the subject was shown four pictures, one of which showed someone writing, he could immediately point it out in response to the question. "Although in a verbal sense he was not aware of what he had done, in some nonverbal sense, he was," explains Zaidel.

Now that they are better able to communicate with one hemisphere at a time, the researchers are developing nonverbal tests (since the right hemisphere is completely speechless despite its ability to comprehend words and to read and write somewhat). They also hope to test for personality differences between the two sides of the brain. So far, judging from its reactions to pictures of the subject's self, acquaintances, belongings, pets and public figures, the right hemisphere seems to have a characteristic social, political, personal and self-awareness roughly comparable to that of the left brain.

The implications of Sperry's findings reach into practically every arena of psychology and beyond. In the field of therapy, it offers hope for those who have suffered severe brain damage if we can learn ways to train one hemisphere to take over the job of the other in it absence. It challenges the priorities of our educational system, which is almost totally geared to the development of the left hemisphere, missing what may be tremendous untapped potentials of the right hemisphere. "Our educational system and modern society generally discriminate against one whole half of the brain," says Sperry.

There may be critical periods for the development of different talents, some experts believe. Music and foreign languages can be learned very readily at an early age, but later these subjects become more difficult. If there are critical periods for the development of the right hemisphere's mechanical ingenuity, for instance, it may be necessary to train it at that age or lose forever the possibility of realizing its full potential. "It could be that females in general, if exposed to mechanical toys, would be more adept as adults at this kind of mental activity," suggests Sperry.

Such experiments also tip the scale in the age-old heredity-versus-environment argument back in the direction of the importance of heredity after many years' swing in the opposite direction. Minds are not infinitely malleable in response to their experience, it seems to show. Certain brain circuits appear to be genetically preprogrammed to develop in certain ways.

Perhaps most far-reaching is the fact that the psyche seems inextricably embedded in the physiology of the brain. If consciousness is the crucial element in reestablishing some of the dignity and freedom psychology has denied us of late, the work of Sperry and his colleagues seems to show not only that consciousness exists, but that it is dual in nature and is a vital force in the workings of the human mind. HB