One final note related to this issue involves a development in animal research[redacted]public concerns about potential mistreatment. The city of Cambridge, [redacted] major research centers of the world with institutions such as Harvard Univers[redacted]MIT, created the position of Commissioner of Laboratory Animals within the[redacted]partment of Health and Hospitals. This was the first such governmental p[redacted]ition and is currently held by a veterinarian, Dr. Julie Medley. Cambridg[redacted] home to 22 research laboratories that house approximately 60,000 a[redacted]ls. The commissioner's charge is to ensure humane and proper [redacted]ent of all animal subjects in all aspects of the research proce[redacted]he animals' living quarters to the methods used in administeri[redacted]esearch protocols. If a lab is found to be in violation of Cambr[redacted]rict laws concerning the humane care of lab animals, the comm[redacted]er is authorized to impose fines of up to $300 per day. However, D[redacted]ey says she has never had to impose the fine, because any facility t[redacted]s been found in violation, willingly and quickly corrects the problem [redacted]sonal communication, September 2003).

Th[redacted]studies you are[redacted]efited all of huma[redacted]arying degrees. The histor[redacted]ogical research is a relatively short one, but it is brimming with the richness[redacted]d excitement of discovering human nature.

ACKNOWLEDGMENTS

I would like to express my sincere gratitude to Charlyce J[redacted]wen, Editorial Director of the Humanities Division at Prentice Hal[redacted]er commitment to and support of this project from the beginn[redacted] editions ago. I am also deeply grateful to Jayme Heffler, P[redacted]Acquisitions Editor at Prentice Hall for her valued support, [redacted], and friendship over the past 5 years. I extend my personal ap[redacted] to Bruce Kenselaar for continuing to lend his considerable tal[redacted]designing the cover of this and past editions. My genuine gratitu[redacted]es out to my psychology colleagues in the field who have taken th[redacted]e, interest, and effort to communicate to me their comments, suggestion[redacted]nd wisdom relating to past edition[redacted] I have attempted at every [redacted]pportunity to inc[redacted]manuscript. Thanks[redacted]reviewers whose thoughtful input [redacted]d guide my changes [redacted] additions in the fourth edition: Barbara Ann Cabral,[redacted]alinde Althaus, Susan Sprecher, Robert D. Boroff, Sherman Sowby, Debra L. [redacted]lden, Paul D. Young, Kathleen M. Greaves, Bailey Drechsler, Travis Lang[redacted], Tara Lynn Torchia, M. Betsy Bergen, Lynne Kemen, Shirley Ogle[redacted] Sandra Caron, and Jennifer L. O'Loughlin-Brooks.

Finally, to my students, friends, and [redacted] many colleges and universities who have particip[redacted]ory of this book in many tangible and intangible wa[redacted]past 12 years (you know who you are), I extend my continuin[redacted]wishes and heartfelt thanks.

ROGER R. HOCK

1 BIOLOGY AND HUMAN BEHAVIOR

Nearly all general psychology texts begin with chapters relating to the biology of human behavior. This is not simply due to convention, but rather it is because biological processes form the basis of *all* behavior. Each of the other subfields of psychology rests on this biological foundation. The branch of psychological research that studies these processes is called *physiological* or *biological psychology*, and focuses on the interaction of your brain and nervous system, the processes of receiving stimulation and information from the environment through your senses, and the ways in which your brain organizes all this information to create your perceptions of the world.

The studies chosen to represent this basic component of psychological research include a wide range of research and are among the most influential and most often cited. The first study discusses a famous research program on right-brain/left-brain specialization that shaped much of our present knowledge of how the brain functions. Next is a study that surprised the scientific community by demonstrating how a stimulating "childhood" might produce a more highly developed brain. The third study represents a fundamental change in the thinking of many psychologists about the basic causes of human behavior, personality, and social interaction, namely, a new appreciation for the significance of your *genes*. Fourth is the invention of the famous "visual cliff" method of studying infants' abilities to perceive depth. All these studies, the latter two in particular, also address an issue that underlies and connects nearly all areas of psychology and provides for an ongoing and fascinating debate: the nature-nurture controversy.

ONE BRAIN OR TWO?

Gazzaniga, M. S. (1967). The split brain in man. *Scientific American, 217* (2), 24–29.

You are probably aware that the two halves of your brain are not the same and that they perform different functions. For one thing, the left side of your brain is responsible for movement in the right side of your body, and vice versa. Even beyond this, though, the two brain hemispheres appear to have even greater specialized abilities.

It has come to be rather common knowledge that, for most of us, the left brain controls the ability to use language while the right is involved more in spatial relationships, such as those needed for artistic activities. It is well known that stroke or accident victims who suffer damage to the left side of the brain will usually lose their ability to speak (often this skill returns with practice and training). Many people believe that each half, or "hemisphere," of your brain may actually be a completely separate mental system with its own individual abilities for learning, remembering, perceiving the world, and even feeling emotions. The concepts underlying this popular awareness are the result of many years of rigorous scientific research on the effects of splitting the brain into two separate hemispheres.

Research in this area was pioneered by Roger W. Sperry (1913–1994), beginning about 15 years prior to the article examined in this chapter. In his early work with animal subjects, Sperry made many remarkable discoveries. For example, consider a cat that has had surgery to cut the connection between the two halves of its brain and to alter its optic nerves so that its left eye only transmitted information to the left hemisphere and the right eye only to the right hemisphere. Following surgery, the cat appeared to behave normally and exhibited virtually no ill effects. Then the cat's right eye was covered, and the cat learned a new behavior, such as walking through a short maze to find food. After the cat became skilled at maneuvering through the maze, the eye cover was shifted to its left eye. Now when the cat was placed in the maze, its left brain had no idea where to turn and the animal had to relearn the entire maze from the beginning.

Sperry conducted many related studies over the next 30 years and in 1981 received the Nobel Prize for his work on the specialized abilities of the two halves of the brain. When his research endeavors turned to human subjects in the early 1960s, he was joined in his work by Michael Gazzaniga. Although Sperry is considered the founder of split-brain research, Gazzaniga's article has been chosen because it is a clear, concise summary of their early collaborative work with human subjects and is cited consistently in many general psychology texts. Its selection is in no way intended to overlook or overshadow either Sperry's leadership in this field or his great contributions. Gazzaniga, in large part, owes his early research, and his ongoing leadership in the area of hemispheric specialization, to Roger W. Sperry (see Sperry, 1968; Puente, 1995).

To understand split-brain research, some knowledge of human physiology is required. The two hemispheres of your brain are in constant communication with one another via the *corpus callosum,* a structure made up of about 200 million nerve fibers. If your corpus callosum is cut, this major line of communication is disrupted, and the two halves of your brain must then function independently. So, if we want to study each half of your brain separately, all we need to do is surgically sever your corpus callosum.

But can scientists divide the brains of humans? This sounds like psychology by Dr. Frankenstein! Obviously, research ethics would never allow such drastic methods simply for the purpose of studying the specialized abilities of the brain's two hemispheres. However, in the late 1950s, the field of medicine provided psychologists with a golden opportunity. In some people with very rare and very extreme cases of uncontrollable epilepsy, seizures could be virtually eliminated by surgically severing the corpus callosum. This operation was (and is) extremely successful, as a last resort, for those patients who cannot be helped by any other means. When this article was written in 1966, 10 such operations had been undertaken, and four of the patients consented to participate in examination and testing by Sperry and Gazzaniga to determine how their perceptual and intellectual skills were affected as a result of this surgical treatment.

THEORETICAL PROPOSITIONS

The researchers wanted to explore the extent to which the two halves of the human brain are able to function independently, and whether they have separate and unique abilities. If the information traveling between the two halves of your brain is interrupted, would the right side of your body suddenly be unable to coordinate with the left? If language is controlled by the left side of the brain, how would your ability to speak and understand words be affected by this surgery? Would thinking and reasoning processes exist in both halves separately? If the brain is really two separate brains, would a person be capable of functioning normally when these two brains are no longer able to communicate? Since we receive sensory input from both the right and the left, how would the senses of vision, hearing, and touch be affected? Sperry and Gazzaniga attempted to answer these and many other questions in their studies of split-brain individuals.

METHOD

The researchers developed three types of tests to explore a wide range of mental (cognitive) capabilities of the patients. One was designed to examine visual abilities. They devised a technique to allow a picture of an object, a word, or parts of words to be transmitted only to the visual area (called a "field") in *either* the right- or left-brain hemisphere, but not to both. Normally, both of your eyes send information to both sides of your brain. However, with exact placement of items or words in front of you, and with your eyes fixed on a specific point, images can be fed to only the right or the left visual field of your brain.

Another testing situation was designed for tactile (touch) stimulation. Here, participants could feel, but not see an object, a block letter, or even a word in cutout block letters. The apparatus consisted of a screen with a space under it for the subject to reach through and touch the items without being able to see them. The visual and the tactile devices could be used simultaneously so that, for example, a picture of a pen could be projected to one side of the brain and the same object could be searched for by either hand among various objects behind the screen (see Figure 1).

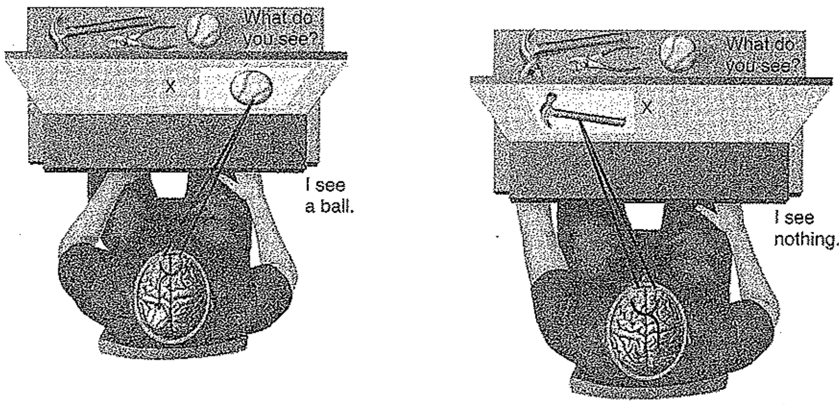

FIGURE 1 A typical visual testing device for split-brain subjects.

Finally, testing auditory abilities was somewhat more tricky. When sound enters either of your ears, sensations are sent to both sides of your brain. Therefore, it is not possible to limit auditory input to only one side of the brain even in split-brain patients. However, it is possible to limit the *response* to such input to one brain hemisphere. Here is how this was done. Imagine that several common objects (a spoon, a pen, a marble) are placed into a cloth bag, and you are then asked, verbally, to find certain items by touch. You would probably have no trouble doing so. If you place your left hand in the bag, it is being controlled by the right side of your brain, and vice versa. Do you think either side of your brain could do this task alone? As you will see in a moment, both halves of the brain are not equally capable of responding to this auditory task. What if you are not asked for specific objects, but are simply requested to reach into the bag and identify objects by touch? Again, this would not be difficult for you, but it would be quite difficult for a split-brain patient.

Gazzaniga combined all of these testing techniques to reveal some fascinating findings about how the brain functions.

RESULTS

First of all, you should know that following this radical brain surgery, the patients' intelligence level, personality, typical emotional reactions, and so on were relatively unchanged. They were very happy and relieved that they were now free of seizures. Gassaniga reported that one patient, while still groggy from surgery, joked that he had "a splitting headache." When testing began, however, these subjects demonstrated many unusual mental abilities.

Visual Abilities

One of the first tests involved a board with a horizontal row of lights. When a patient sat in front of this board and stared at a point in the middle of the lights, the bulbs would flash across both the right and left visual fields. However, when the patients were asked to explain what they saw, they said that only the lights on the right side of the board had flashed. Next when the researchers flashed only the lights on the left side of the visual field, the patients claimed to have seen nothing. A logical conclusion from these findings was that the right side of the brain is blind. Then an amazing thing happened. The lights were flashed again, only this time the patients were asked to point to the lights that had flashed. Although they had said they only saw the lights on the right, they pointed to all the lights in both visual fields. Using this method of pointing, it was found that both halves of the brain had seen the lights and were equally skilled in visual perception. The important point here is that when the patients failed to *say* that they had seen all the lights, it was not because they didn't see them, but because the center for speech is located in the brain's left hemisphere. In other words, in order for you to say you saw something, the object has to have been seen by the left side of your brain.

Tactile Abilities

You can try this test yourself. Put your hands behind your back. Then have someone place familiar objects (a spoon, a pen, a book, a watch) in either your right or your left hand and see if you can identify the object. You would not find this task to be very difficult, would you? This is basically what Sperry and Gazzaniga did with the split-brain patients. When an object was placed in the right hand in such a way that the patient could not see or hear it, messages about the object would travel to the left hemisphere and the patient was able to name the object and describe it and its uses. However, when the same objects were placed in the left hand (connected to the right hemisphere), the patients could not name them or describe them in any way. But did the patients *know* what the object was? In order for the researchers to find out, they asked the subjects to match the object in their left hand (without seeing it, remember) to a group of various objects presented to them. This they could do as easily as you or I. Again, this places verbal ability in the left hemisphere of the brain. Keep in mind that the reason you are able to name unseen objects in your left hand is that the information from the right side of your brain is transmitted via the corpus callosum to the left side, where your center for language says "that's a spoon!"

Visual Plus Tactile Tests

Combining these two types of tests provided support for the findings above and also offered additional interesting results. If subjects were shown a picture of an object to the right hemisphere only, they were unable to name it or describe it. In fact, there might be no verbal response at all or even a denial that anything had been presented. But if the patients were allowed to reach under the screen with their left hand and touch a selection of objects, they were always able to find the one that had been presented visually.

The right hemisphere was found to be able to think about and analyze objects as well. Gazzaniga reported that when the right hemisphere was shown a picture of an item such as a cigarette, the subjects could touch 10 objects behind the screen that did not include a cigarette, and select an object that was most closely related to the item pictured—in this case an ashtray. He went on to explain:

> Oddly enough, however, even after their correct response, and while they were holding the ashtray in their left hand, they were unable to name or describe the object or the picture of the cigarette. Evidently, the left hemisphere was completely divorced, in perception and knowledge, from the right. (p. 26)

Other tests were conducted to shed additional light on the language-processing abilities of the right hemisphere. One very famous, ingenious, and revealing use of the visual apparatus came when the word HEART was projected to the patients so that HE was sent to the right visual field and ART was sent to the left. Now, keeping in mind (your connected mind) the functions of the two hemispheres, what do you think the patients verbally reported seeing? If you said ART, you were correct. However, and here is the revealing part, when the subjects were presented with two cards with the words HE and ART printed on them and asked to point with the left hand to the word they had seen, they all pointed to HE! This demonstrated that the right hemisphere is able to comprehend language, although it does so in a different way from the left: in a nonverbal way.

The auditory tests conducted with the patients produced similar results. When patients were asked to reach with their left hand into a grab bag hidden from view and pull out certain specific objects (a watch, a marble, a comb, a coin) they had no trouble. This demonstrated that the right hemisphere was comprehending language. It was even possible to describe a related aspect of an item with the same accurate results. An example given by Gazzaniga was when the patients were asked to find in a grab bag full of plastic fruit "the fruit monkeys like best," they retrieved a banana. Or when told "Sunkist sells a lot of them," they pulled out an orange. However, if these same pieces of fruit were placed out of view in the patients' left hand, they were unable to say what they were. In other words, when a verbal response was required, the right hemisphere was unable to speak.

One last example of this amazing difference between the two hemispheres involved plastic block letters on the table behind the screen. When patients were asked to spell various words by feel with the left hand they had an easy time doing so. Even if three or four letters that spelled specific words were placed behind the screen, they were able, left-handed, to arrange them correctly into words. However, immediately after completing this task, the subjects could not name the word they had just spelled. Clearly, the left hemi-

sphere of the brain is superior to the right for speech (in some left-handed people, this is reversed). But in what skills, if any, does the right hemisphere excel? Sperry and Gazzaniga found in this early work that visual tasks involving spatial relationships and shapes were performed with greater proficiency by the left hand (even though these patients were all right-handed). As can be seen in Figure 2, copying three-dimensional drawings (using the pencil behind the screen) was much more successful with the left hand.

Finally, the researchers wanted to explore emotional reactions of split-brain patients. While performing visual experiments, Sperry and Gazzaniga suddenly flashed a picture of a nude woman to either the left or right hemisphere. In one instance, when this picture was shown to the left hemisphere of a female patient:

> She laughed and verbally identified the picture of a nude. When it was later presented to the right hemisphere, she said . . . she saw nothing, but almost immediately a sly smile spread over her face and she began to chuckle. Asked what she was laughing at, she said: "I don't know . . . nothing . . . oh—that funny machine." Although the right hemisphere could not describe what it had seen, the

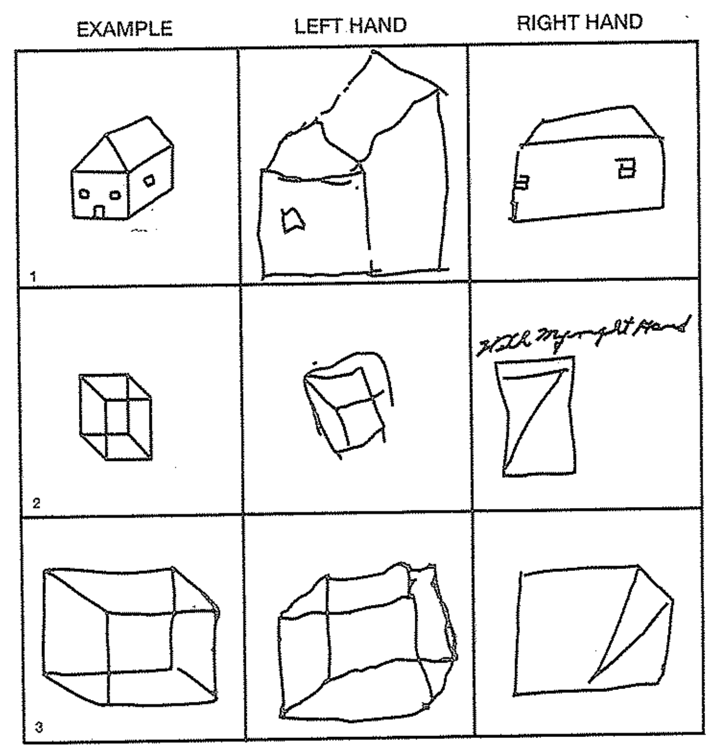

FIGURE 2 Drawings made by split-brain patients. (Adapted from "The Split Brain in Man," by Michael S. Gazzaniga.)

sight nevertheless elicited an emotional response like the one evoked in the left hemisphere. (p. 29)

DISCUSSION

The overall conclusion drawn from the research reported in this article was that there are two different brains within each person's cranium, each with complex abilities. Gazzaniga notes the possibility that if our brain is really two brains, then perhaps we have the potential to process twice as much information if the two halves are divided. Indeed, there is some research evidence to suggest that split-brain patients have the ability to perform two cognitive tasks as fast as a normal person can carry out one.

SIGNIFICANCE OF FINDINGS

These findings and the subsequent research carried out by Sperry and Gazzaniga and others are extremely significant and far-reaching. We now know that the two halves of your brain have many specialized skills and functions. Your left brain is "better" at speaking, writing, mathematical calculation, and reading and is the primary center for language. Your right hemisphere, however, possesses superior capabilities for recognizing faces, solving problems involving spatial relationships, symbolic reasoning, and artistic activities.

Our increased knowledge of the specialized functioning of the brain allows us to treat victims of stroke or head injury more effectively. By knowing the location of the damage, we can predict what deficits are likely to exist as the patient recovers. Through this knowledge, therapists can employ appropriate relearning and rehabilitation strategies to help patients recover as fully and quickly as possible.

Gazzaniga and Sperry, after years of continuous work in this area, concluded that each hemisphere of your brain really is a mind of its own. In a later study, split-brain patients were tested on much more complex problems than have been discussed here. One question asked was, "What profession would you choose?" A male patient verbally (left hemisphere) responded that he would choose to be a draftsman, but his left hand (right hemisphere) spelled by touch in block letters *automobile race* (Gazzaniga & LeDoux, 1978). In fact, Gazzaniga has taken this theory a step further. He now maintains that even in people whose brains are normal and intact, there may not be complete communication between the two hemispheres (Gazzaniga, 1985). For example, if certain bits of information, such as those forming an emotion, are not stored in a language format, the left hemisphere may not have access to it. The result of this is that you may feel sad and not be able to say why. Since this is an uncomfortable cognitive situation, the left hemisphere may try to find a verbal reason to explain the sadness (after all, language is its main job). However, since your left hemisphere does not have all the necessary data, its explanation may actually be wrong!

CRITICISMS

The findings from the split-brain studies carried out over the years by Sperry, Gazzaniga, and others have rarely been disputed. The main body of criticism about this research has focused instead on the way the idea of right- and left-brain specialization has filtered down to popular culture and the media.

There is now a widely believed myth that some people are more *right-brained* or more *left-brained*, or that one side of your brain needs to be developed in order for you to improve certain skills. Jarre Levy, a psychobiologist at the University of Chicago, has been in the forefront of scientists who are trying to dispel the notion that we have two separately functioning brains. She claims that it is precisely because each hemisphere has separate functions that they must integrate their abilities instead of separating them, as is commonly believed. Through such integration, your brain is able to perform in ways that are greater than and different from the abilities of either side alone.

When you read a story, for example, your right hemisphere is specializing in emotional content (humor, pathos), picturing visual descriptions, keeping track of the story structure as a whole, and appreciating artistic writing style (such as the use of metaphors). While all this is happening, your left hemisphere is understanding the written words, deriving meaning from the complex relationships among words and sentences, and translating words into their phonetic sounds so that they can be understood as language. The reason you are able to read, understand, and appreciate a story is that your brain functions as a single, integrated structure (Levy, 1985).

In fact, Levy explains that no human activity uses only one side of the brain. "The popular myths are interpretations and wishes, not the observations of scientists. Normal people have not half a brain, nor two brains, but one gloriously differentiated brain, with each hemisphere contributing its specialized abilities" (Levy, 1985, p. 44).

RECENT APPLICATIONS

The continuing influence of Sperry's and Gazzaniga's split-brain research echoes the quote from Levy. A review of recent medical and psychological literature reveals numerous articles in various fields referring to the early work and methodology of Roger Sperry as well as to more recent findings by Gazzaniga and his associates. For example, a study from 1998 conducted in France (Hommet & Billard, 1998) has questioned the very foundations of Sperry's and Gazzaniga's studies, namely, that severing the corpus callosum actually divides the hemispheres of the brain. The French study found that children who were born without a corpus callosum (a rare brain malformation) demonstrated that information was being transmitted between their brain hemispheres. The researchers concluded that significant connections other than the corpus callosum must exist in these children. Whether such subcortical connections are indeed present in split-brain individuals remains unclear.

Later that same year, a study was published by a team of neuropsychologists that included Gazzaniga, from several prestigious research institutions in the United States (University of Texas, Stanford, Yale, and Dartmouth). The study demonstrated that split brain patients may routinely perceive the world differently from the rest of us (Parsons, Gabrieli, Phelps, & Gazzaniga, 1998). The researchers found that when subjects were asked to identify whether drawings presented to only one brain hemisphere were drawn by right- or left-handed people, the split-brain patients were only able to do so correctly when the handedness of the artist was the *opposite* of the hemisphere to which the picture was projected. Normal control subjects were correct regardless of which hemisphere "saw" the drawings. This implies that communication between your brain hemispheres is necessary for imagining or simulating in your mind the movements of others, that is, "putting yourself in their place" in order to perceive their actions correctly.

Finally, researchers continue to explore the idea that our two brain hemispheres have separate, yet distinct consciousnesses. One such study (Morin, 2001), focused on the idea of inner speech (internal dialogue with and about yourself) as a signpost for self-awareness and consciousness. Morin proposed that your self-awareness may be quite different in your right and left cerebral hemispheres due to the greater ability of the left brain for language. However, the right brain may have the ability to perceive "the self" in a physical or bodily way, rather than through an awareness of mental processes. Therefore, Morin suggested an alternative interpretation of commissurotomy [surgical separation of the corpus callosum] according to which split-brain patients exhibit two uneven streams of self-awareness: a "complete" one in the left hemisphere and a "primitive" one in the right hemisphere" (p. 594).

Some have carried this idea a step further and applied it to some psychological disorders, such as dissociative, multiple personality disorder (e.g., Schiffer, 1996). The idea behind this notion is that in some people with intact, "nonsplit" brains, the right hemisphere may be able to function at a greater-than-normal level of independence from the left, and may even take control of a person's consciousness for periods of time. Is it possible that multiple personality disorder might be the expression of hidden personalities contained in our right hemispheres? It's something to think about . . . with *both* of your hemispheres.

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[redacted]

Rosenzweig, M. R., Bennett, E. L., & Diamond, M. C. [redacted] changes in response to experience. *Scientific American, 226* (2), 22–29.

If you were to enter the baby's room in a typical Ameri[redacted]-class home today, you would probably see a crib full [redacted] and various colorful toys dangling directly over [redacted] reach of the infant. Some of these toys may light up, [redacted] music, or do all three. What do you suppose is the reasoning [redacted] supplying infants with so much to see and do? Well, aside from [redacted] fact that babies seem to enjoy and respond positively to these things, [redacted] most parents' belief, acknowledged or not, that children need a stim[redacted]ting environment for optimal intellectual development and proper dev[redacted]opment of the brain.

[redacted] produce physical changes in the [redacted] philosophers and scientists for centuries. In 1785, Malacarne, an Italian ana[redacted]died pairs of dogs from the same litter and pairs of birds from the same ba[redacted] of eggs. For each pair, he would train one subject extensively over a long pe[redacted]od of time while the other would be equally well cared for, but not traine[redacted] He discovered later, in autopsies of the animals, that the brains of the tra[redacted]ed animals appeared more complex, with a greater number of folds [redacted] fissures. However, this line of research was, for unknown reasons, [redacted]tinued. In the late nineteenth century, there were attempts [redacted] the circumference of the human head with the amount [redacted] a person had experienced. While some early findings [redacted] such a relationship, later research determined that this was [redacted] valid measure of brain development.

By the 19[redacted] new technologies had been developed that gave scientists the ability [redacted] measure brain changes with great precision using high magnification t[redacted]niques and assessment of levels of various brain enzymes and neurotran[redacted]mitter chemicals. Mark Rosenzweig and his colleagues Edward Bennett and M[redacted]an Diamond, at the University of California at Berkeley, incorporated those te[redacted] period of 10 years to try to address the issue of the effect of experience [redacted] brain. Their findings were reported in the article discussed in this chapter. [redacted] reasons that will become obvious, they did not use humans in their studi[redacted] but rather, as in many classic psychological experiments, their subjects were r[redacted]s.

THEORETICAL PROPOSITIONS

Since psychologists are ultimately interested in humans [redacted], the use of nonhuman subjects must be justified. In [redacted], part of the theoretical foundation concerned [redacted] chosen as subjects. The authors explained th[redacted] reasons, it is more convenient to use rodents than to use hig[redacted] mammals such as carnivores or primates. The part of the brain